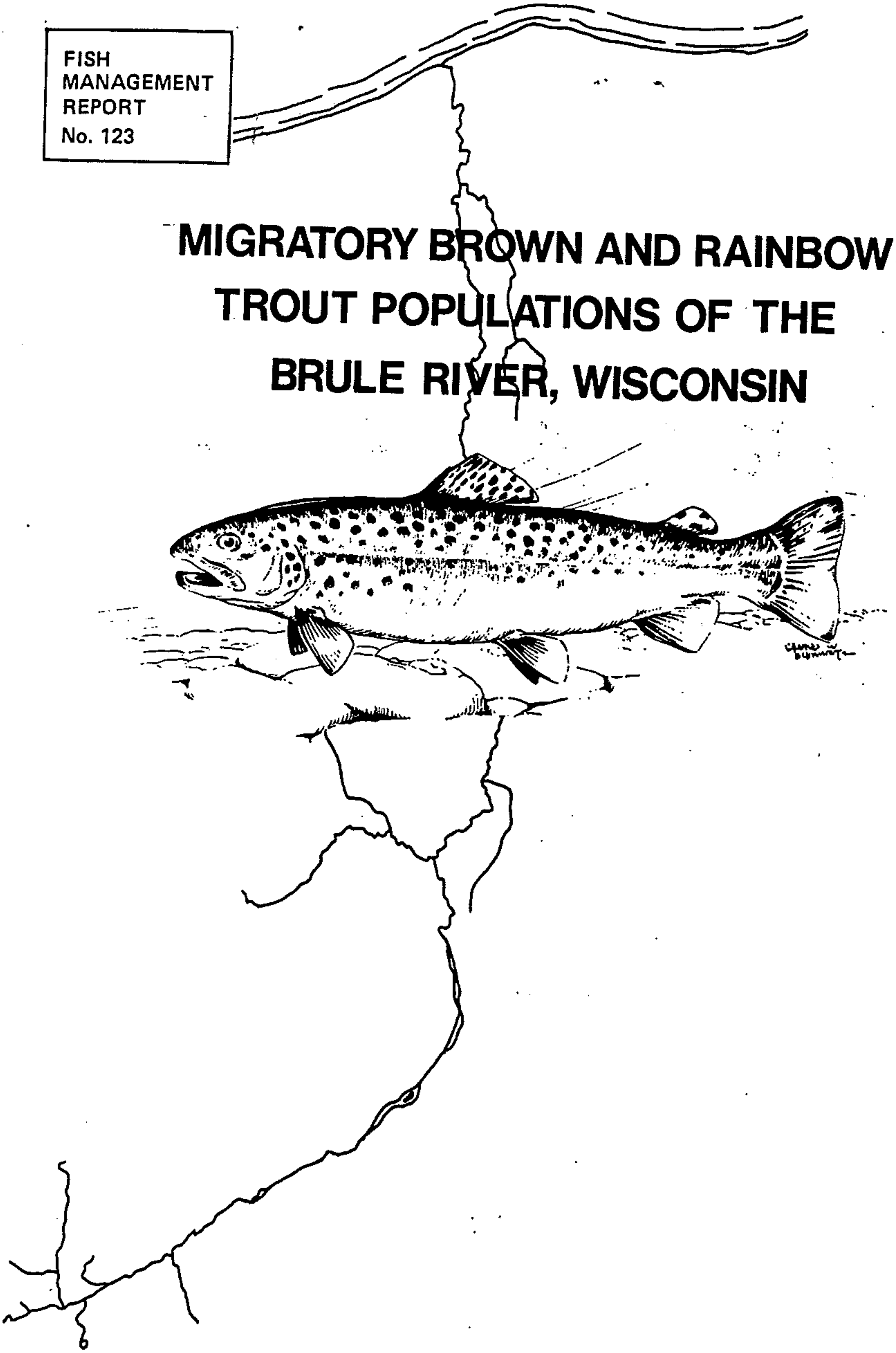
FISH MANAGEMENT REPORT
No. 123

MIGRATORY BROWN AND RAINBOW TROUT POPULATIONS OF THE BRULE RIVER, WISCONSIN



Department of Natural Resources Madison, Wisconsin 1984

A comprehensive study of migratory brown and rainbow trout populations in the Brule River was conducted from 1977 through 1980 to assess changes and trends in the fishery which occurred since a similar study from 1961 through 1964. Fish population information was collected using a mechanical weir and by electrofishing. Pressure and harvest information was obtained by a creel survey.

Numbers (based on catch per unit effort), size structure, and age structure of migratory brown trout in the 1978 and 1979 spawning runs were similar to those found during the early 1960's. Brown trout on the spawning run averaged approximately 22 inches in length during both studies, with age IV trout as the most abundant age class.

Rainbow trout increased considerably both in numbers and average size and age since the early 1960's. Average length in the spawning run increased from 20.4 inches to approximately 25 inches during the present study. Older fish (ages V and VI) dominated the spawning population during this study than during the early 1960's when ages III, IV, and V were dominant.

The increase in numbers and average size of rainbow trout may be attributable to the reduction in sea lamprey numbers in Lake Superior during the 1960's. Periodic outbreaks of furunculosis, which killed a high percentage of spawning brown trout, probably prevented increases in numbers and average size of brown trout similar to those experienced by rainbow trout.

Size and age distributions and mortality patterns showed no indication of overharvest of either brown or rainbow trout, nor did natural reproduction appear to be a limiting factor to trout populations. Observations on ages of downstream migrating smolts indicated that the factors most limiting to trout populations may be food and/or cover for juvenile trout.

Returns from tagged trout caught in Lake Superior indicate that brown trout do not travel far from the Brule River, while rainbow trout range over a large area of western Lake Superior.

Creel survey data showed that total fishing pressure and annual harvest of migratory adult brown and rainbow trout was higher than during a 1973 creel survey, yet the average size of harvested rainbow trout during the present survey was still larger than in 1973.

The Pacific salmons have not had any visible adverse effects on Brule River trout fisheries. Chinook and coho salmon reproduction has been documented in the Brule River system; and a third species, the pink salmon, also spawns in the Brule River.

Management recommendations are aimed at maintaining and improving the "high quality" or "trophy" characteristic of the Brule River fishery.

MIGRATORY BROWN TROUT AND RAINBOW TROUT POPULATIONS OF THE BRULE RIVER, WISCONSIN

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INTRODUCTION

From 1961 through 1964, an intensive study of migratory trout in the Brule River was conducted by Niemuth (1967, 1970). Since that time, various changes have occurred regarding use of the Brule River, its management, and the fish community of Lake Superior. These changes may have had an impact, favorable or unfavorable, upon migratory trout populations in recent years.

Control of sea lampreys* began on the Great Lakes in the early 1950's with mechanical and electrical barriers on sea lamprey spawning streams. Operation of an electrical barrier on the Brule River began in 1957 and continued through 1979. Chemical lamprey control using 3-trifluoromethyl-4-nitrophenol (TFM) began in Lake Superior tributaries in 1958. First chemical treatment of the Brule River took place in 1959 and continues today at approximately 3-year intervals. The first noticeable decrease in lamprey populations in Lake Superior did not occur until 1962, when adult lamprey populations were suddenly reduced to only 19% of the 1958-61 mean (Dees 1974; Smith 1971). Lamprey populations have remained at low levels to the present time. Since sea lamprey numbers did not significantly decrease until 1962, any reduction in their damaging effects on fish populations, as reflected by changes in numbers or average size of Brule River trout, would not yet have been completely evident during the 1961-64 study.

Introductions of Pacific salmon species into Lake Superior have recently caused concern as to possible effects on trout populations in the Brule River. Coho salmon and chinook salmon were introduced into Lake Superior in 1966 and 1967, respectively, and have since found their way into the Brule River. Pink salmon were first introduced in 1956, but significant runs in the Brule River did not occur until the late 1970's. These species could affect the well-established trout populations in the Brule River by competing for available food, cover, and spawning areas.

Anglers have expressed concern in recent years that brown trout populations, for various reasons, may have declined; and that rainbow trout, or steelheads, are being overharvested. Suggested management alternatives by the public have included more restrictive creel limits and stocking.

Increases in pressure on the Brule River by other user groups have caused public concern that trout stocks are being adversely affected. Canoe traffic on the Brule River increased from an estimated 3,650 user days in 1967 to 19,115 user days in 1978 (Brule River State Forest Records). Floating the river on inner tubes became an extremely popular and controversial pastime which was eventually banned in 1982. Some fishermen believed that such user groups physically damaged the stream habitat.

Because of the various changes that have occurred in the Brule River and Lake Superior, and the concerns that they have generated, a comprehensive study of migratory trout populations in the Brule River began in 1977 to assess changes and trends in the fishery since the early 1960's. This study was specifically

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*Scientific names of fish may be found in Appendix A.

designed to look at numbers, sizes, growth rates, mortality rates, distribution, migration patterns, and other aspects of the life histories of migratory brown and rainbow trout in the Brule River. Information on status of other salmonid species in the Brule River was collected concurrently. In addition, a one-year creel survey was conducted to assess fishing pressure, catch rates, and total harvest. For comparative purposes, much of the project design was similar to that of the previous study by Niemuth (1967, 1970).

STUDY AREA

PHYSICAL DESCRIPTION

The Brule River (also known as the Bois Brule River) lies in eastern Douglas County, Wisconsin, entirely within the boundary of the Brule River State Forest. The river is approximately 48 miles in length and flows northward into Lake Superior (Fig. 1). From its source to the mouth, the river drops 420 ft, of which 328 ft are within the lower 19 miles of river (Bean and Thomson 1944). Total watershed area is about 190 miles^2.

The headwaters of the Brule River flow through a broad, flat bog area with numerous springs which extends downstream to the area of Cedar Island. The uppermost stretches, known as the East and West Forks, are characterized by a bottom substrate of mostly hard sand and areas of silt, with scattered gravel areas in the uppermost portions. Wilson Creek, which enters the West Fork, and the outlet creek from Beaupre Springs entering the East Fork, both have large amounts of gravel suitable for trout spawning. Of the two, the Beaupre Springs outlet has the most stable flow. A series of beaver flowages on the Beaupre Springs outlet had for years caused considerable warming of the water, but these beaver dams have been removed. Much of the area from the confluence of the East and West Forks downstream to Stone's Bridge (Co. Hwy. S) is characterized by relatively slow current, silt bottom, and dense tag alder growth. Below Stone's Bridge, the river widens and has many scattered boulders.

Downstream from Cedar Island the river flows through a series of wide, shallow "lakes"; the largest of which are known as Big Lake, Lucius Lake, and Spring Lake. Big Lake, the uppermost and largest of the three, has a surface area of 41 acres. River gradient begins to increase rapidly from this area downstream, and becomes a series of short rapids. Nebagamon Creek enters the Brule River downstream from Co. Hwy. B (Winneboujou). This stream originates at the outlet of Lake Nebagamon and water temperatures are relatively warm as a result. Blueberry Creek, a tributary to Nebagamon Creek, is a high quality trout stream. Another major tributary of the Brule River, the Little Brule River, enters the main river at U.S. Hwy. 2. The Little Brule is also a high quality trout stream, and is the water source for a state-operated trout rearing station.

From U.S. Hwy. 2 downstream to just above Copper Range Campground (Co-op Park), the Brule River meanders through an area known as the "meadows", characterized by slower flow and many deep pools.

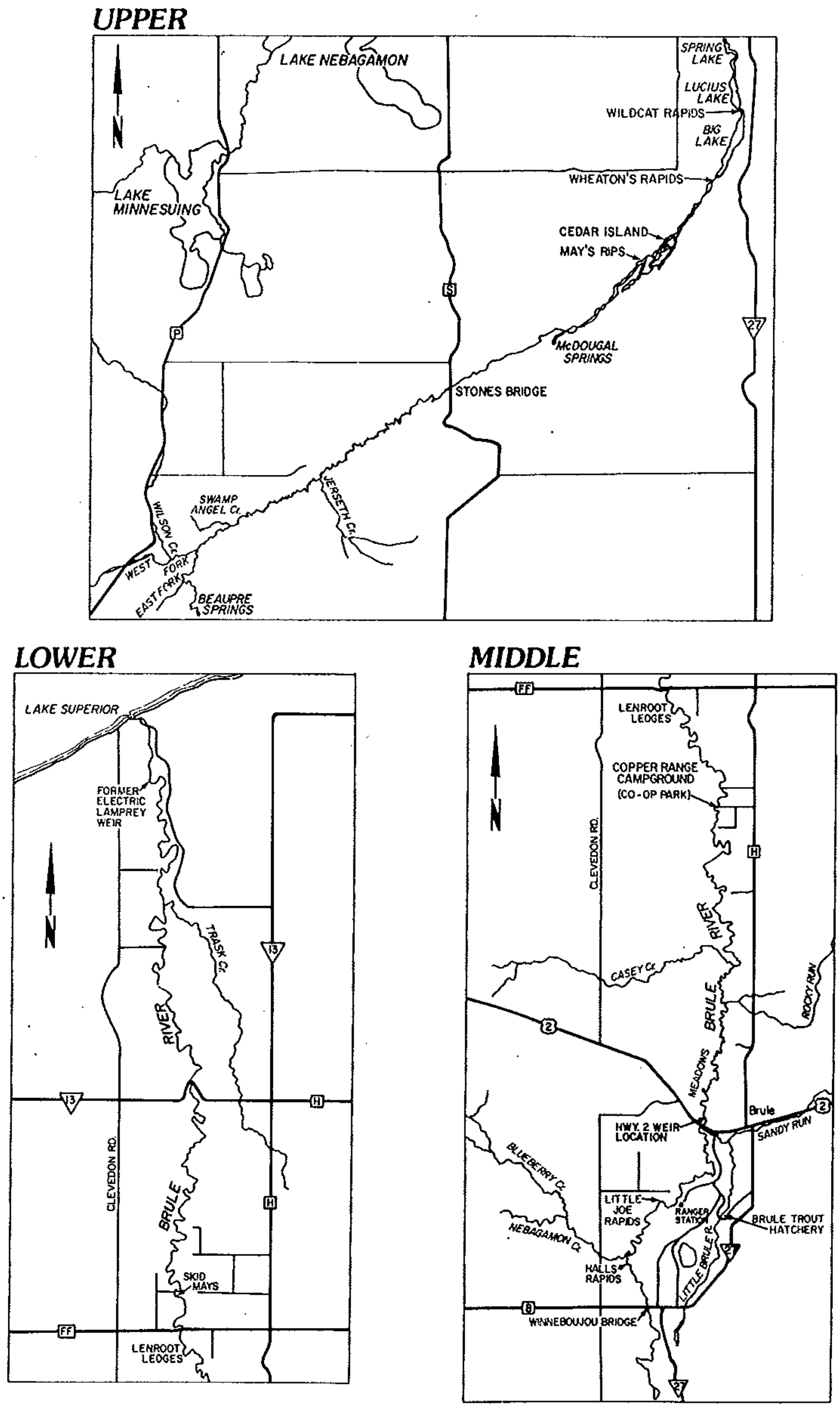


FIGURE 1. Upper, middle and lower sections of the Brule River, showing tributary streams and locations.

From its headwaters to Copper Range, the Brule River flows through a region of glacial drift underlain by igneous bedrock. From Copper Range to Lake Superior, the river flows through glacial lake deposits of heavy red clay soils underlain by sandstone.

River gradient increases sharply from Copper Range almost to Lake Superior, becoming an almost continuous series of rapids. This portion of the river flows through a narrow valley with steep clay banks, which results in some degree of turbidity through most of the year.

Water quality data, collected monthly at State Hwy. 13 by Wisconsin Department of Natural Resources (DNR) personnel (G. Sevener pers. comm.) show an average total alkalinity of 58 mg/l $CaCO_3$, and a hardness of 59 mg/l (1976 data), placing it in the mid-range of alkalinity among area streams. Mean total alkalinity for Douglas County streams was 66 mg/l (Sather and Johannes 1972). Monthly pH readings averaged 7.6, while dissolved oxygen averaged 11.8 mg/l (1980 data).

The Brule River is known for its stable flow characteristics. A river stability index, calculated by dividing low summer flow by average flow, placed the Brule River highest (most stable) among 36 Wisconsin streams for which flow data were available (Sather and Johannes 1972). Flow data from a U.S. Geological Survey gauging station located at the DNR Brule Area Headquarters show a 22-year average flow of 169 cfs, with a range from 67 to 1520 cfs (Niemuth 1967). Volume of flow farther downriver is greater, while flow stability is lower due to the narrow valley and heavy clay soils resulting in greater runoff.

Aquatic vegetation ranges from sparse to extensive in different areas of the Brule River. Dense growths of aquatics are found in the middle section of the river, especially in the lakes (Big, Lucius, Spring). Growth of aquatics is probably limited in the upper sections by the extremely soft organic mud bottom and by the dark color of the water, while plant growth in the lower Brule River is limited by clay turbidity and the swift current. Common aquatic plant species found in the Brule River include Anacharis sp., pondweed (Potamogeton spp.), coontail (Ceratophyllum sp.), water milfoil (Myriophyllum sp.), buttercup (Ranunculus sp.), arrowhead (Sagittaria spp.), burreed (Sparganium sp.), and water moss (Fontinalis sp.). A detailed description of aquatic plants and bank flora of the Brule River is found in Thomson (1944).

HISTORICAL AND FISHERY BACKGROUND

The Brule River has long been recognized as one of the more famous trout rivers in Wisconsin and the midwest. The Brule River has a colorful past history (Marshall 1954, Jerrard 1956), much of which stems from its being the shortest natural waterway between Lake Superior and the upper Mississippi basin. With only a short portage linking the headwaters of the Brule and the St. Croix River, this waterway became a familiar and important route to Indians, explorers, traders, soldiers, and government agents.

Records of the earlier explorers mentioned the difficulty of navigation on the river due to hundreds of beaver dams (O'Donnell 1944). Intensive trapping in the early 1800's removed most of the beaver and dams from the Brule, and it was not until the 1830's that there was any mention of an abundance of trout.

By the 1870's an intense interest was developing in the trout fishery, and some records report tremendous catches of trout. Several U.S. presidents have been attracted to the Brule River for its trout fishing.

Brook trout were the only trout species originally inhabiting the Brule River. Natural lake-run brook trout populations occurred in other Lake Superior tributaries and, although historical documentation is lacking, it may be assumed that brook trout populations in the Brule River were historically made up of at least some migratory fish. The first supplemental stocking of brook trout began in 1894 (O'Donnell 1945) and continued almost annually through 1979.

Rainbow trout were first introduced into the Brule River in 1892 (O'Donnell 1945). Periodic rainbow trout stocking was continued through 1981. The strong migratory tendencies of rainbow trout have resulted in annual spawning runs of these "steelhead" trout from Lake Superior. Juvenile rainbow trout (known as "parr") spend one or more years in the river before descending to Lake Superior, at which time they are known as "smolts". These trout then spend one or more years feeding on the more abundant food supply in Lake Superior, during which time they increase dramatically in size before returning to the Brule River to spawn.

The Brule River has traditionally had two distinct runs of rainbow trout, even though both groups spawn during spring. Some rainbow trout enter the river during fall and spend the winter months in the deeper holes of the lower river. These fish continue upstream to spawning areas as water temperatures rise in spring. The other group of rainbow trout enters the river during

A large male rainbow trout in spring, showing the dark coloration of rainbows that enter the Brule River during the fall and overwinter in the river.

spring and moves immediately upstream to spawn. Rainbow trout fresh from Lake Superior have a bright, silvery lustre. After spending some length of time in the river, most rainbow trout lose this lustre, becoming darker and taking on a red or pink coloration on the sides of the body, which is more pronounced in males. These two groups of rainbow trout can often be distinguished during spring by the difference in coloration.

Much of the fame and popularity of the Brule River as a trout stream in recent years can be attributed to the steelhead runs. This popular sport fishery attracts heavy fishing pressure during spring and fall.

Brown trout were first introduced into the Brule River in 1920 (O'Donnell 1945), and were periodically stocked through 1974. Since that time, two apparently distinct populations have developed: a population of stream-resident brown trout that spends its entire life cycle within the river, and a lake-run brown trout population that has a life history very similar to that of rainbow trout. Little is known of the interactions between stream-resident and migratory brown trout, or of the amount, if any, of genetic distinctness between the two populations.

As with rainbow trout, migratory brown trout lose the typical coloration of stream trout while in the Lake Superior environment, taking on a silvery gray or brown color with irregular dark spots. Because of this color change, migratory brown trout were for many years mistakenly considered a distinct species, known locally as "sebagos" or "sebago salmon". From 1943 through 1955, "sebagos" were harvested commercially from Lake Superior.

Migratory brown trout provide a less popular sport fishery than rainbow trout, mainly owing to the fact that they are harder to catch. Nevertheless, they do provide a trophy trout fishery during late summer, before the steelheads have entered the river.

The Brule River has for many years had special early and late fishing seasons in addition to the statewide general season, to take advantage of migratory trout runs. Season dates have varied considerably. The first early season took place in 1935, while the first extended fall season took place in 1948. From 1957 through 1981, the early trout season on the Brule River from the mouth upstream to U.S. Hwy. 2 began on the Saturday nearest April 1 and ran until the opening of the general season. From 1975 through 1981, the extended fall season, also from the mouth to U.S. Hwy. 2, ran from October 1 through December 31. Since January 1, 1982, the Brule River below U.S. Hwy. 2 has been open to year-round fishing. The current statewide general trout season runs from the first Saturday in May through September 30.

Length limits and creel limits have also changed over the years. Current limits for trout are 10 inches during the special season and 6 inches during the general season. Present creel limits are 5 trout or salmon in aggregate during the special season and 10 trout or salmon during the general season; except that from the first Saturday in May through May 31, no more than 5 of the 10 fish may be rainbow or brown trout in aggregate.

Fishing pressure is heavy on some parts of the Brule River during the spring steelhead run. Some of this crowding was alleviated by the change to a year-round open season downstream from U.S. Hwy. 2.

The Brule River presently has a diverse fish fauna of 61 species including two hybrids (Append. A). Much of this diversity is a result of the salmonid species, smelt, burbot, or other species which enter the Brule on a seasonal basis. Many other species (e.g., pikes, sunfishes, some suckers) are mainly found in the lower mile of the Brule River which is essentially a lacustrine environment. Species which are associated with the more typical trout water upstream (besides trout) include several minnow species, white suckers, sculpins, darters, and brook lampreys.

METHODS

FISH SAMPLING METHODS

Hwy. 2 Weir

A mechanical two-way fish weir was constructed approximately 500 ft downstream from the U.S. Hwy. 2 bridge at the Town of Brule. This was the same approximate location as the earlier weir used by Niemuth (1967, 1970) in the early 1960's. The weir site was 24.4 miles upstream from Lake Superior and was downstream from most major trout spawning areas.

The weir was constructed of four steel gates, 8 ft long by 3.5 ft high each (the identical gates used on the early 1960's weir) at a slight angle across the river, with a fish trap at each end (Fig. 2). The gates had a series of holes into which 3/8-inch steel rods were placed vertically. With a rod in every hole, the space between the rods was 5/8 inch; with a rod in every second hole, the spaces were 1-5/8 inches. During most of the sampling period, every second hole was used.

Traps measured 6 ft long by 5 ft wide by 5 ft deep, and were constructed of wood with vertical steel rods on the back and sides and two screen funnel openings in front. A screen placed in front of the openings allowed the funnels to be removed when the traps were emptied. The upstream trap was positioned near the east bank, the downstream trap near the west bank. A wakefield of vertical sheet piling was built at an angle from each trap to the bank on both the upstream and downstream sides.

Weir maintenance involved daily raking of leaves and other debris from the gates. Periods of heavy leaf fall in September and October made cleaning necessary around the clock. Periods of high water made it necessary to remove some or all of the rods or to remove the gates entirely. Several incidences of vandalism made additional repairs necessary. Vandalism included break-ins for the purpose of stealing fish, as well as malicious acts of destruction by felling trees across the weir.

The weir was operated from July 22, 1978 through June 13, 1980 during all periods between ice-out and freeze-up as water conditions and weir repair permitted (Table 1). During winter freeze-up, the weir gates, trap funnels, and rods on backs of traps were removed.

Daily operation of the weir included anesthetizing the fish in a metal tank with tricaine methanesulfonate (MS-222) before processing. After data collection and tagging, fish were placed in a holding box in the river to assure complete recovery. Before releasing fish upstream, the holding box was towed a short distance upstream to prevent the fish being swept back against the weir gates.

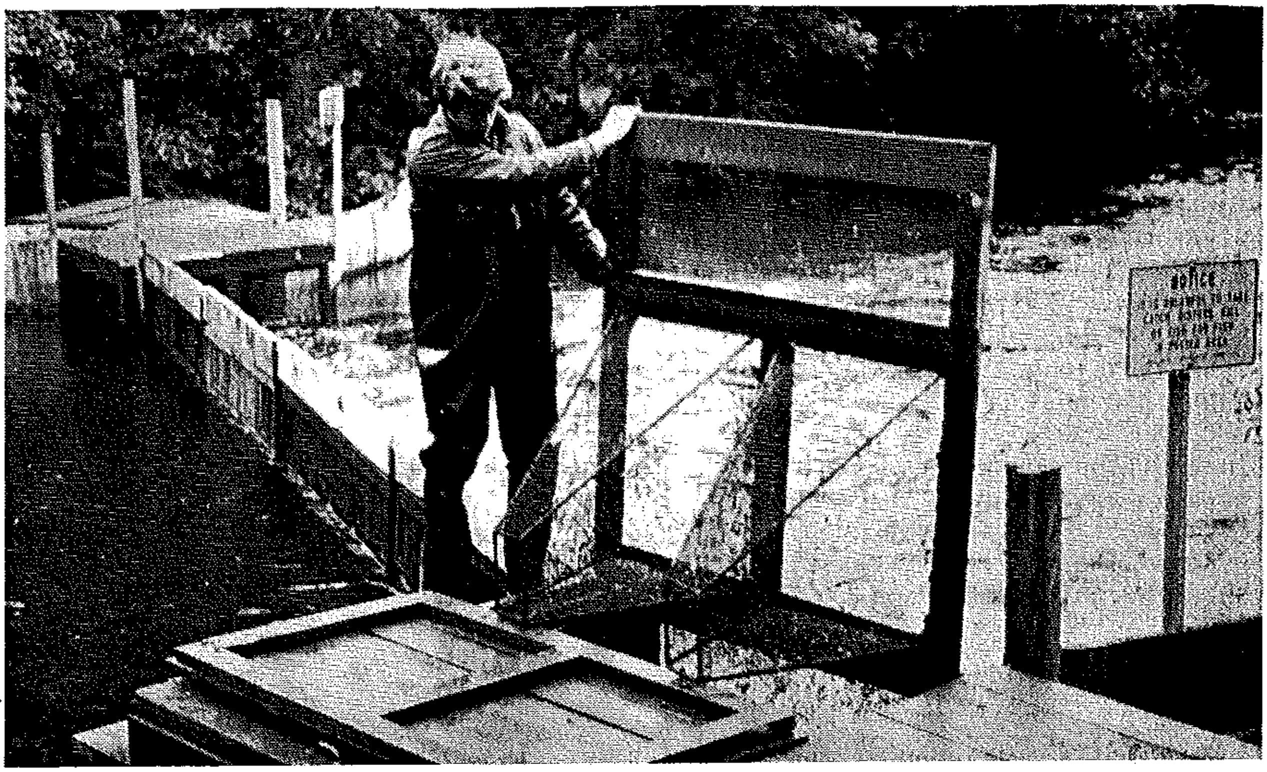


FIGURE 2. Hwy. 2 weir. Upstream trap is in foreground, downstream trap is in background. Direction of flow is from left to right.

TABLE 1. Dates of operation of Hwy. 2 weir and reasons for shutdowns of operation, 1978-80.

Operating Dates		Reason for Shutdown
1978	July 22 - August 15	High water
	August 18 - August 22	High water
	September 8 - September 11	High water
	September 14 - September 22	Vandalism
	October 1 - October 6	High water
	October 9 - November 20	Freeze-up
1979	March 17 - April 17	High water
	May 30 - June 7	High water
	June 27 - July 2	High water
	July 12 - July 31	High water
	August 2 - September 11	High water
	September 14 - September 17	Heavy leaf fall
	September 20 - September 23	Heavy leaf fall
	September 25 - October 20	High water
	November 1 - December 1	Freeze-up
1980	March 15 - April 6	High water
	April 11 - April 20	High water and vandalism
	April 25 - June 13	End of project

Electrofishing

Electrofishing gear was used to sample portions of the river to obtain information on trout migration, reproduction, and to tag additional fish. A 230-volt AC boom shocker mounted on an 18-ft boat was used to electrofish the lower mile of the river several times during the falls of 1978 and 1979. The river was not navigable farther upstream with this gear. In October of 1979, a 230-volt, pulsed DC mini boom shocker was used to electrofish the upper river from Wheaton's Rapids up to a mile above Cedar Island, and from a mile below Co. Hwy. S to 2 miles above it. This was a smaller (14-ft), more maneuverable boat that was better suited to work in faster water with rocks and other obstacles.

In addition to surveys in the main river, several tributaries to the Brule were surveyed during the summers of 1978 through 1980, including the East Fork, West Fork, Wilson Creek, Little Brule River, Casey Creek, and Blueberry Creek. These streams were electrofished using a 230-volt AC portable stream shocking unit.

Electric Lamprey Weir

Some sampling was done at the electrical sea lamprey weir operated by the U.S. Fish and Wildlife Service as time and work schedules permitted. This weir was located 1 mile upstream from the mouth of the Brule River, and was operated from 1957 through 1979, when it was dismantled. This weir was first operated strictly as a lamprey control device, but later functioned mainly as an index station after chemical lamprey control with TFM began in 1959. Upstream migrating fish were blocked by an electrical field and caught in traps where they could be sorted and processed. Some downstream migrating fish were also caught in the traps after passing through the electrical field.

Trapnetting

A trap net was set several times during the summer and fall of 1979 and once during spring of 1980 in Lake Superior off the mouth of the Brule River, in an attempt to capture additional trout before they entered the river. The trap net had a single pot measuring 8 ft long by 6 ft wide by 6 ft deep, with a heart entrance 18 ft wide. A 100-ft lead of 2-inch stretch mesh was used in 1979; in 1980 an additional 300-ft lead of 4-1/2-inch mesh was added. The pot was set in water ranging from 12 to 23 ft deep, with the lead running toward shore.

DATA COLLECTION AND FISH TAGGING

Weather and Physical Measurements

Minimum and maximum air and water temperatures were recorded daily at the Hwy. 2 weir, using a Taylor recording thermograph. Percent cloud cover and precipitation were also noted.

River level was read daily from a gauge graduated in 0.02 ft intervals, mounted at an arbitrary height in the river.

Fish Data Collection

Basic fish data collection included total length to the nearest 0.1 inch, weight to the nearest ounce, and sex. Sex determination of trout was most easily based on jaw characteristics, with males having a pronounced long, hooked lower jaw near spawning time in both rainbow and brown trout. Another characteristic sometimes used when jaw characteristics were indistinct was the fact that scales were much more difficult to remove from males than from females.

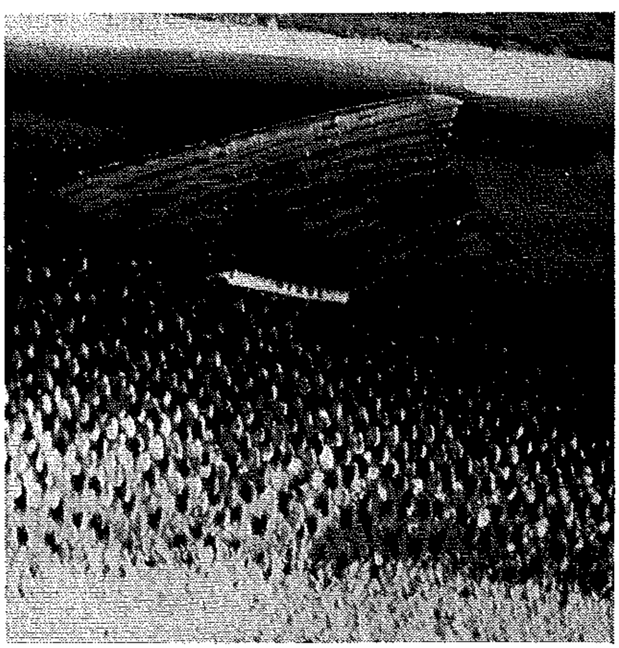
Any abnormalities of trout captured were noted. These included lamprey scars, spinal deformities, hooking injuries or other jaw deformities, body wounds, torn fins, disease, and fungus.

Scale samples for aging were taken from an area just below the insertion of the dorsal fin of brown and rainbow trout.

Tagging and Fin Clipping

Nearly all migratory trout and salmon captured were tagged, except for those that were in a very unhealthy condition at the time of capture. In addition, several of the larger stream-resident brown trout were tagged.

Tags used were Floy FD-67C and FD-68B anchor tags printed with a number for each individual fish and either "D.N.R. Box 80, Brule, WI" or "DNR, Brule, WI". Orange tags were used on brown trout, yellow tags on rainbow trout, and purple tags on other species. Lengths of tags varied from 3 inches during



The short Floy tag used during much of the study.

fall 1978 and spring 1979, 2.2 inches during fall 1979, and 1.6 inches in spring of 1980.

Tags were inserted into the fish at the base of the dorsal fin, locking the tag anchor between the interneural spines. Tags seemed to anchor most firmly when placed in the thick fleshy spot at the insertion of the dorsal fin.

Anglers returning tags were sent a letter giving the date the fish was tagged, length and weight at time of tagging, location where tagged, and any other pertinent information on that particular fish.

During August 9-15, 1978, a sample of brown trout was alternately tagged (81 fish) and fin clipped with a right pectoral clip (82 fish) in an effort to determine whether tagging had an effect on mortality of brown trout or susceptibility to furunculosis. Right pectoral fin clips were also used on 59 brown trout smolts and 105 rainbow trout smolts captured at the electric lamprey weir during June, 1979.

AGE AND GROWTH

Ages of fish were determined by scale analysis. Scales were read from impressions in plastic using a Bausch and Lomb microprojector. Anterior scale radius and radius to each annulus was measured directly from the projection for growth determination.

Plots of body length on scale radius showed good linear relationships for rainbow and brown trout under 11 inches (smolts) and also for trout over 13 inches (upstream migrants). In both species, however, the slopes of regressions differed slightly between the two size groups, increasing in brown trout and decreasing in rainbow trout for the larger size group. Body-scale relationships that were finally used for growth calculations were based only on scales from smolts, for reasons discussed later. Back calculations of lengths at previous ages were made using a nomograph similar to one described by Carlander and Smith (1944).

SPAWNING OBSERVATIONS

The upper Brule River was canoed from Co. Hwy. S to Co. Hwy. B or from Co. Hwy. S to the Ranger Station during late March or early April from 1977 through 1980, to visually count numbers of spawning rainbow trout and redds. These counts were qualitative indices of fish abundance as they were affected by water temperatures and light conditions.

CREEL SURVEY

A creel survey of the Brule River fishery was conducted from July 1, 1978 through June 30, 1979, during the open fishing season periods. Downstream from U.S. Hwy. 2 (often referred to as the "lower river") the creel survey period ran from July 1 through the close of the late season (December 31), and from the start of the early trout season (March 31) through June 30. Upstream from U.S. Hwy. 2 (often referred to as the "upper river") the creel survey period ran from July 1 through September 30 (close of the regular trout season), and from May 5 (opening of the regular trout season) through June 30.

Each creel check consisted of one day's angler interviews and an instantaneous vehicle count along the river, and was done according to a random stratified schedule to sample various times of the day and week. Six creel checks were scheduled during each two-week period, three of which were scheduled on weekends. Time of day for creel checks was either 6 a.m. to 2 p.m. or 2 p.m. through 10 p.m.. An equal number of early and late checks were made during the survey.

Twenty-one checkpoints were sampled along the river. These checkpoints corresponded with those used by Swanson (DNR, unpubl.) in a 1973 creel survey on the Brule River. This information is available in a DNR intra-department memorandum filed at the Brule Area office.

Instantaneous vehicle counts were made at all known parking areas along the river, and were done as quickly as possible to avoid double counting of cars which may have moved from one site to another. Wisconsin resident and nonresident vehicles were tallied separately.

As many anglers as possible were interviewed during each sampling day. Information gathered from each angler included: location(s) fished, time fishing began, time fishing ended (if fishing was completed for the day), state of residence, number of anglers in party, number of successful anglers (caught at least one fish), and numbers and lengths of any fish that were harvested. No records were kept of fish that were caught and released.

Analysis of creel survey data was done by computer using a standard program developed by DNR. No anglers were interviewed during December 1979 due to the low fishing pressure at that time; therefore, the December instantaneous vehicle counts could not be analyzed by the program and were excluded. The early trout season in 1979 opened on March 31, so March creel survey results are derived from only one sampling day. Although the regular trout season in 1979 opened on May 5, computer analysis of data divided results by calendar month; so for ease of reporting, the first four days in May were also considered part of the regular season.

RESULTS AND DISCUSSION

PHYSICAL MEASUREMENTS

Air temperature data from the DNR weather station at Brule show comparable monthly averages during summer and fall for 1978 and 1979 (Append. B). Winter and spring temperatures during 1980 were considerably milder than in 1979. The average air temperature for the 2-year period of the study was 40 F.

Corresponding water temperatures at the Hwy. 2 weir showed trends similar to air temperatures during the same periods (Appends. C and D). The dates of last ice in the river were similar for 1979 and 1980 (April 5 and April 3, respectively). Annual water temperature averages were not calculated because of the lack of data during some months. The lower Brule River is actually marginal trout water during summer due to high water temperatures, which were recorded as high as 76 F during the study.

Precipitation records from the DNR weather station show highest summer-fall totals during 1978 and highest spring totals during 1979 (Append. E). The unusually light snowfall during winter 1979-80 and low rainfall during spring 1980 resulted in less extreme river level fluctuations and more consistent weir operation (Append. F). The weir was usually inoperable when the river gauge level was above approximately 1.5 ft for extended periods, as extreme water force could damage the weir. The extreme increase in water level during August, 1978 reflects a one-day total rainfall of 5.11 inches on August 23.

MOVEMENT AND CATCH

One or both of the migratory trout species can be found in the Brule River during nearly any time of year, with least likely periods being the months of June and early July. Brown trout begin running upriver during July, and seem to move upstream relatively slowly, as spawning does not take place until October. The fall run of rainbow trout typically moves upstream rather slowly also, since spawning does not occur until spring; however, as water temperatures warm during spring, these fish seem to move upstream quickly to spawning areas while the spring-run rainbow trout enter the Brule River and migrate immediately to spawning areas.

Hwy. 2 Weir Catch

Catch of migratory brown trout at the Hwy. 2 weir began the first day of weir operation (July 22) in 1978 and on July 16 in 1979. Peak catches occurred from mid-August through the first week of September. Some upstream migrant brown trout were captured as late as November 22 in 1979.

Upstream movement of brown trout, as reflected by daily weir catch, seemed to be triggered by periods of rainfall (Fig. 3), even though the resulting rise in water level may have been relatively subtle (Append. E). Not all peaks in daily catch can be explained by precipitation. Water temperature alone showed little relation to brown trout migration, but may have an effect in combination with water level fluctuations and darkness. It is likely that large numbers of brown trout bypassed the weir during periods when high water halted weir operation.

Upstream migrating rainbow trout were captured at the Hwy. 2 weir as early as August 1 in 1978 and July 19 in 1979. Although scattered individuals were captured all through late summer and fall during both years, significant catches did not occur until approximately October 15 through November 20. No upstream migrants were captured after November 22.

Spring weir operation began on March 17, 1979 and March 15, 1980, and large numbers of rainbow trout were captured immediately. In 1979 within the first

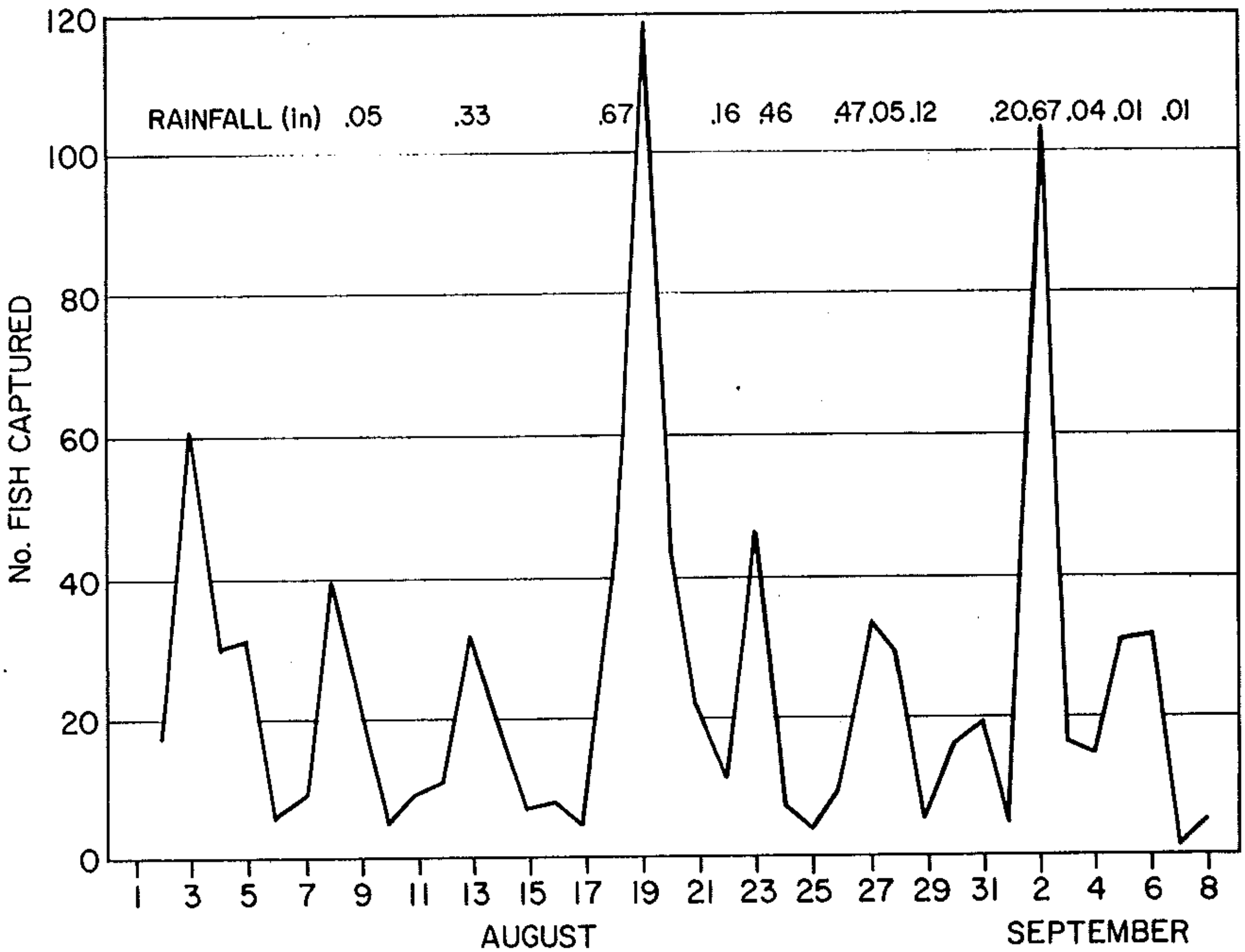


FIGURE 3. Daily catch of upstream migrant brown trout at the Hwy. 2 weir in relation to rainfall amounts.

32 days, 1,638 upstream migrants were captured, after which time high water postponed weir operation until May 31. In 1980 water levels were more favorable for weir operation, and upstream migrants were captured through June 3. Upstream movement of rainbow trout appeared to be triggered by increases in water temperature (Fig. 4). Catch of rainbow trout in the weir often dropped sharply when daily low water temperatures fell below 34 or 35 F.

Because of inherent biases involved in estimating size of a migratory fish population, no actual estimates of numbers were made. The catch of brown and rainbow trout at the Hwy. 2 weir can best be compared with the earlier study by Niemuth (1967, 1970) by examining monthly catch totals and corresponding days of weir operation each month. Numbers of migratory brown trout captured in 1978 and 1979 were slightly higher but probably not significantly different than numbers captured during the early 1960's (Table 2). Days of operation per month in 1978 were similar or fewer than days of operation in 1963, yet total catches were nearly identical (1,255 in 1963; 1,263 in 1979).

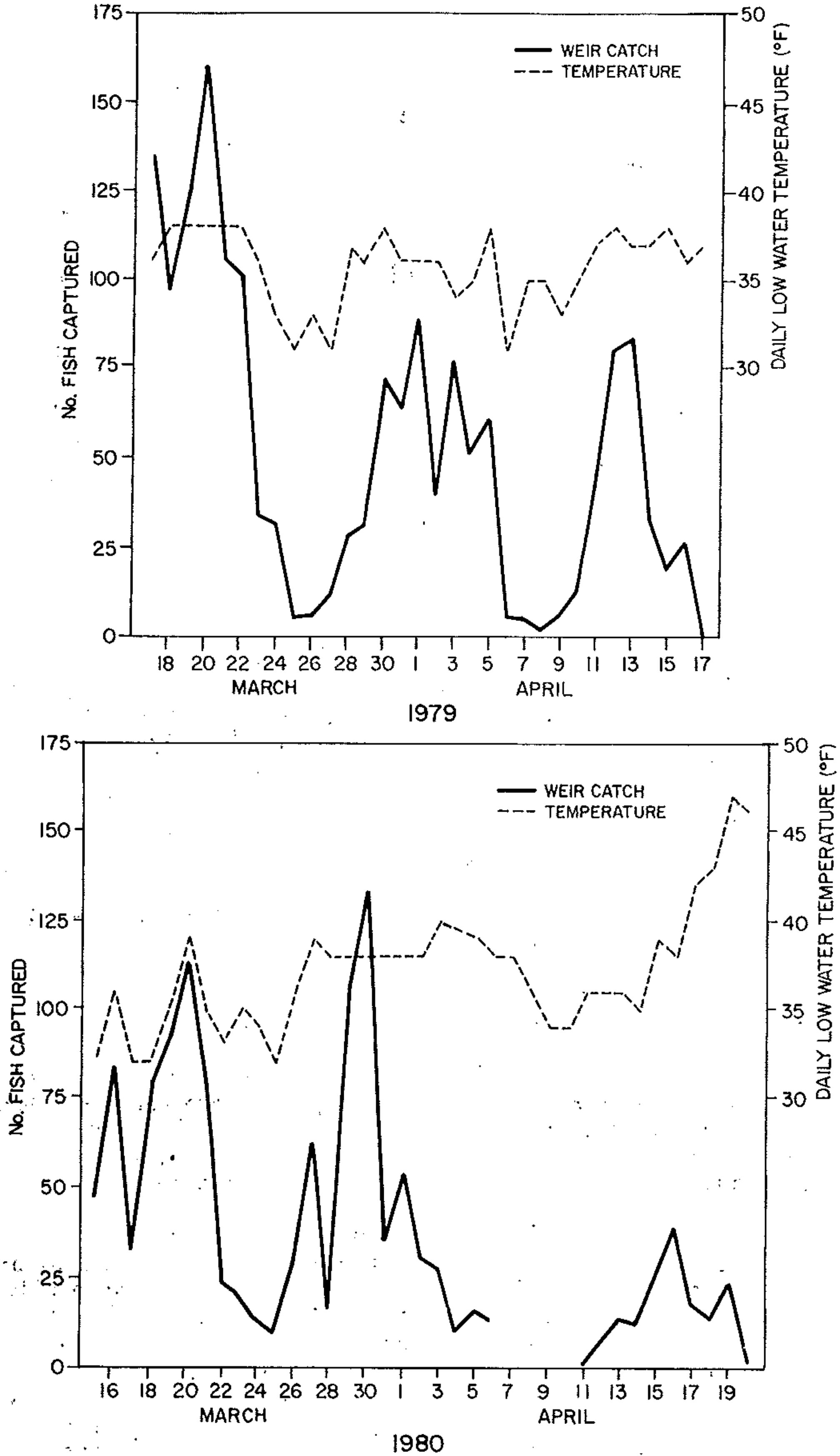


FIGURE 4. Daily catch of upstream migrant rainbow trout at the Hwy. 2 weir in relation to daily low water temperatures.

Numbers of rainbow trout captured in the weir in 1978 and 1979 were significantly higher during both spring and fall than numbers captured during the early 1960's (Table 3). Highest monthly catch totals during both studies were in March. During March 1963, 27 rainbows were captured, while monthly catch totals for March 1979 and 1980 were 1,006 and 972, respectively, during a comparable number of trap days. Highest total catch during the earlier study for the period of September through November was 20 rainbows during 91

TABLE 2. Numbers of upstream migrant brown trout captured at the Hwy. 2 weir in the first study (Niemuth 1967) and present study.

	First Study			Present Study	
Month	1962	1963	1964	1978	1979
January	--	--	1 (7)	--	--
February	--	0 (11)	--	--	--
March	--	0 (17)	--	--	0 (15)
April	--	0 (23)	0 (6)	--	0 (17)
May	--	0 (28)	--	--	1 (2)
June	--	0 (30)	--	--	0 (10)
July	--	98 (31)	1 (21)	111 (9)	177 (21)
August	136 (17)*	716 (31)	235 (31)	354 (20)	724 (30)
September	92 (30)	172 (27)	13 (13)	47 (15)	302 (24)
October	75 (31)	152 (31)	18 (29)	72 (27)	36 (19)
November	67 (30)	117 (30)	66 (20)	28 (20)	23 (30)
December	16 (13)	--	--	--	0 (1)

*Number of days of operation.

TABLE 3. Numbers of upstream migrant rainbow trout captured at the Hwy. 2 weir in the first study (Niemuth 1970) and present study.

	First Study			Present Study		
Month	1962	1963	1964	1978	1979	1980
January	--	--	0 (7)	--	--	--
February	--	0 (11)	--	--	--	--
March	--	27 (17)	--	--	1,006 (15)	972 (17)
April	--	18 (23)	5 (6)	--	632 (17)	401 (22)
May	--	0 (28)	--	--	5 (2)	146 (31)
June	--	0 (30)	--	--	13 (10)	2 (13)
July	--	1 (31)	0 (21)	0 (9)	1 (21)	--
August	0 (17)*	3 (31)	0 (31)	5 (20)	11 (30)	--
September	0 (30)	2 (27)	0 (13)	14 (15)	18 (24)	--
October	20 (31)	12 (31)	2 (29)	95 (27)	24 (19)	--
November	0 (30)	1 (30)	15 (20)	54 (20)	81 (30)	--
December	8 (13)	--	--	--	0 (1)	--

*Number of days of operation.

trap days in 1962, while totals for the same period in 1978 and 1979 were 163 and 123 during 62 and 73 trap days, respectively. Total catch for the year 1963 was 64 rainbows, while in 1979 during similar or fewer trap days per month, 1,791 rainbow trout were captured.

Downstream movement of spawned out brown trout based on weir catch is consistent with data during the 1960's (Niemuth 1967) in that a large downstream migration occurs during October, November, and again the following March (Table 4). It is unknown if there is much movement during the winter months, especially under ice cover. We believe that during the mild winter of 1979-80, many browns may have moved downstream, resulting in the relatively low downstream catch in March 1980.

Downstream weir catch of spawned out rainbow trout showed heaviest movement during April as well as large numbers during May (Table 5). Limited data during the 1960's (Niemuth 1970) is consistent as to time of migration.

TABLE 4. Numbers of downstream migrant brown trout captured at the Hwy. 2 weir.

Month	1978	1979	1980
January	--	--	--
February	--	--	--
March	--	52 (15)	10 (17)
April	--	5 (17)	6 (22)
May	--	0 (2)	0 (31)
June	--	0 (10)	0 (13)
July	0 (9)*	0 (21)	--
August	0 (20)	0 (30)	--
September	2 (15)	6 (24)	--
October	61 (27)	4 (19)	--
November	47 (20)	73 (30)	--
December	--	0 (1)	--

*Number of days of operation.

TABLE 5. Numbers of downstream migrant rainbow trout captured at the Hwy. 2 weir.

Month	1978	1979	1980
January	--	--	--
February	--	--	--
March	--	24 (15)	15 (17)
April	--	302 (17)	291 (22)
May	--	0 (2)	101 (31)
June	--	3 (10)	1 (13)
July	0 (9)*	0 (21)	--
August	0 (20)	0 (30)	--
September	0 (15)	0 (24)	--
October	0 (27)	1 (19)	--
November	1 (20)	6 (30)	--
December	--	0 (1)	--

*Number of days of operation.

Electrofishing Catch

Based on electrofishing surveys in the lower mile of the Brule River, rainbow trout were found to enter the river from mid-September through the first week of November, although no sampling was done after November 6 (Table 6). Electrofishing effort (distance sampled) on each sampling date was similar, so number of rainbow trout captured may be compared. Greatest numbers of rainbow trout apparently entered the river during early October, which was consistent with findings by Niemuth (1970) in the early 1960's. Niemuth, who sampled this stretch of river in the spring as well, concluded that the influx of rainbows from the lake during fall was greater than in spring. In addition to upstream migrating rainbows, 10 adult lake-run brown trout were also captured on fall surveys during the present study.

Electrofishing surveys were also conducted on the upper river during October 1979. Large numbers of migratory brown trout were found on the spawning areas immediately above and below Cedar Island, but only one migratory brown in the stretches above and below Stones Bridge where there are few areas with suitable spawning substrate (Table 7). A total of 205 juvenile migratory and stream resident brown trout were also captured in these surveys; of these, 31 (15%) were less than 5 inches in length.

A total of 19 migratory rainbow trout were captured on these surveys, most of which were in the area from Cedar Island downstream to Wheaton's Rapids (Table 8). A total of 161 juvenile and stream resident rainbows were captured, 36 (22%) of which were less than 5 inches in length.

Surveys of six Brule River tributaries found young-of-the-year (YOY) brown and rainbow trout present in all, indicating these streams were important as reproduction and nursery areas (Table 9). Highest numbers of YOY browns (less than 3.5 inches) were found in East Fork and the Little Brule River, while highest numbers of rainbow trout YOY were found in Casey Creek and Blueberry Creek.

TABLE 6. Numbers of upstream migrating rainbow trout captured by electrofishing in the lower mile of the Brule River during fall 1978 and 1979.

1978		1979	
Date	Number Caught	Date	Number Caught
Sep 13	2	Sep 11	2
Oct 5	41	Sep 20	2
Oct 6	21	Sep 27	35
Oct 9	43	Oct 2	46
Oct 11	37	Oct 4	48
Oct 17	20	Oct 10	73
--	--	Oct 24	24
--	--	Nov 6	21

TABLE 7. Numbers of migratory brown trout and juvenile and stream-resident browns captured during electrofishing surveys on the upper Brule River, October 1979.

Area Sampled	Migratory Adults	Juvenile and Stream-Resident Trout
Stones Bridge to 2 miles upstream	1	41
Stones Bridge to 1 mile downstream	0	54
Cedar Island to 1.5 miles upstream	21	54
Cedar Island to Wheaton's Rapids	35	56

TABLE 8. Numbers of migratory rainbow trout and juvenile and stream-resident rainbows captured during electrofishing surveys on the upper Brule River, October 1979.

Area Sampled	Migratory Adults	Juvenile and Stream-Resident Trout
Stones Bridge to 2 miles upstream	1	30
Stones Bridge to 1 mile downstream	0	45
Cedar Island to 1.5 miles upstream	1	50
Cedar Island to Wheaton's Rapids	17	36

TABLE 9. Numbers of young-of-year (less than 3.5 inches) and larger brown and rainbow trout captured during electrofishing surveys of tributaries to the Brule River, 1978-80.

Stream	Date Sampled	Stream Length Sampled (ft)	Brown Trout		Rainbow Trout	
			<3.5 inches	≥3.5 inches	<3.5 inches	≥3.5 inches
East Fork Brule River	June 25-26, 1979	4,000	24	37	10	10
West Fork Brule River	July 9-10, 1979	4,200	2	56	18	34
Wilson Creek	July 20, 1979	605	0	3	16	5
Blueberry Creek	Aug 13-16, 1979	9,500	4	23	398	272
Little Brule River	Aug 7-10, 1978	4,475	23	480	3	195
Casey Creek	Aug 8, 12, 1980	1,100	1	3	176	22

Electric Lamprey Weir Catch

Sampling for trout was done at irregular intervals at the electric lamprey weir from May 18 to July 13, 1979. During this period, 22 downstream migrating adult brown trout were handled and tagged. A total of 131 adult rainbows were handled during this period of which 105 were released upstream and 26 were released downstream of the weir, depending on whether the fish appeared ripe or spent.

Juvenile brown and rainbow trout captured at the weir were assumed to be downstream migrating smolts, and are referred to as such elsewhere in this report. Total numbers of smolts captured at the electric weir show large numbers of both brown and rainbow trout smolts migrating from late May through to the end of weir operation on July 13, with peaks during the latter half of June (Table 10). During this period we measured and took scale samples from 63 brown trout smolts and 113 rainbow trout smolts at the electric weir averaging 7.1 and 6.3 inches in length, respectively (Table 11).

TABLE 10. Numbers and sizes of brown and rainbow trout smolts captured at the electric lamprey barrier on June 4-6, 21-22, and 26-29 and July 6, 1979.

Species	Number in Sample	Mean Length (inches)	Length Range (inches)
Brown trout	63	7.1	4.7 - 8.7
Rainbow trout	113	6.3	4.2 - 10.2

TABLE 11. Numbers of brown and rainbow trout less than 12 inches in length (downstream migrating smolts) captured by the U.S. Fish and Wildlife Service at the Brule River electric lamprey barrier, 1979.

Week Ending	Brown Trout	Rainbow Trout
April 27	2	8
May 4	8	68
May 11	2	9
May 18	3	7
May 25	2	17
June 1	35	58
June 8	57	53
June 15	50	66
June 22	73	228
June 29	72	92
July 6	48	44
July 13	66	63

Trapnet Catch

Trapnetting in Lake Superior off the Brule River mouth on five occasions between June 13 and September 13, 1979 and from May 29 to 30, 1980, for a total of 15 net days, failed to capture any trout or salmon. We believe that trout avoided the net, which was only 6 ft high in water as deep as 23 ft, by swimming over the top.

Catch Summary

In all, a total of 2,247 adult migratory brown trout were captured by all methods for the entire study period; we tagged 2,069 of these. The term "adult" is loosely defined as fish larger than 12 inches, which includes both mature and immature fish returning to the river from Lake Superior. Largest total catch in a sample period was during the fall of 1979 (Table 12).

Catch of adult migratory rainbow trout totalled 4,646; we tagged 4,159. Highest total for a sample period was in spring of 1979 (Table 13).

TABLE 12. Summary of catch statistics from all sampling methods for adult migratory brown trout.

		1978	1979		1980
		Fall	Spring	Fall	Spring
Number captured		731	81	1,411	24
Number tagged		616	78	1,354	21
Number fin clipped		82	0	0	0
Recaptures tagged:	Fall 1978	30	3	8	1
	Spring 1979	--	0	13	0
	Fall 1979	--	--	34	2
	Spring 1980	--	--	--	0
Number released untagged		3	0	2	0

TABLE 13. Summary of catch statistics from all sampling methods for adult migratory rainbow trout.

		1978	1979		1980
		Fall	Spring	Fall	Spring
Number captured		332	2,130	415	1,769
Number tagged		329	1,983	395	1,452
Recaptures tagged:	Fall 1978	1	15	2	2
	Spring 1979	--	130	8	84
	Fall 1979	--	--	5	27
	Spring 1980	--	--	--	197
Number released untagged		2	2	5	7

SIZE STRUCTURE

Length Frequency and Mean Lengths

Length structure of the brown trout population was nearly identical to that of the early 1960's (Niemuth 1967). Overall mean length during the present study was the same (approximately 22 inches) as that during the 1960's (Table 14). Mean lengths based on upstream weir catch were similar to the mean based on electrofishing catch. An overall length frequency shows a range between 12.5 and 33.4 inches and a modal peak between 21.5 and 21.9 inches (Fig. 5). Length structure differed between sexes, consistent with findings during the early 1960's. Both mean lengths and modal sizes (Fig. 6) were greater for male than female brown trout by one inch or more.

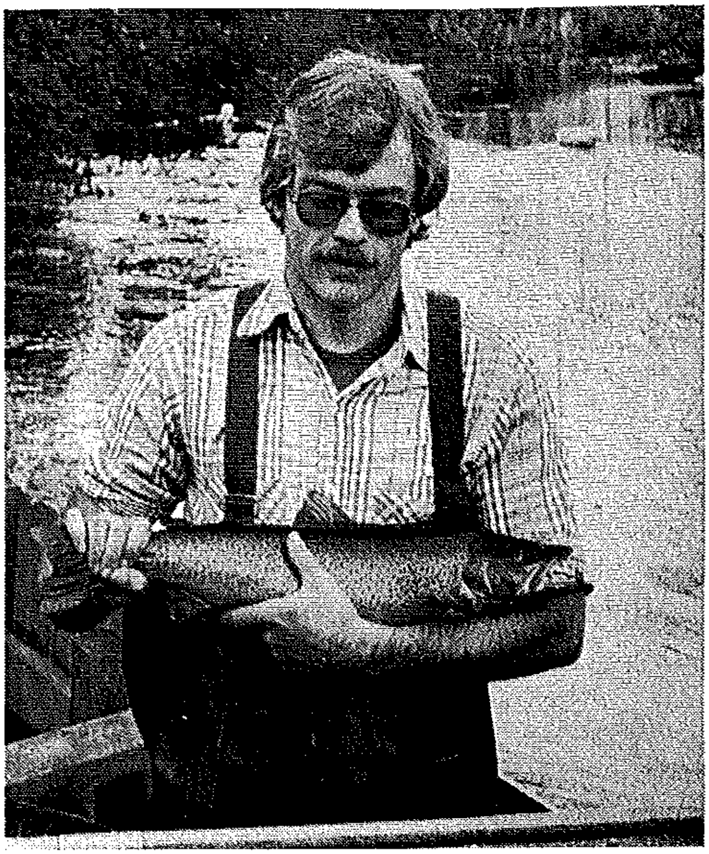
Mean lengths of rainbow trout were near 25 inches overall (Table 14), larger than the overall mean (20.4 inches) during the early 1960's (Niemuth 1970). The latter mean is based on a sample of 795 fish that included the 1961 catch at the "Winnie (Hwy. B) Weir". This weir was operated with rods in the weir screen spaced closer together, allowing for capture of smaller fish. Excluding the 130 rainbows less than 16 inches captured at the "Winnie Weir", the overall mean is still only 21.7 inches.

Mean length of rainbows captured at the U.S. Hwy. 2 weir during the present study was 25.3 inches during spring operation. Mean lengths during fall operation in 1978 and 1979 were smaller (23.4 and 24.2 inches, respectively), and are comparable to mean lengths based on electrofishing samples (23.4 and 23.7 inches respectively) during the same periods. A greater upstream movement by the small, immature males ("skipjacks") during fall would account for the smaller average length.

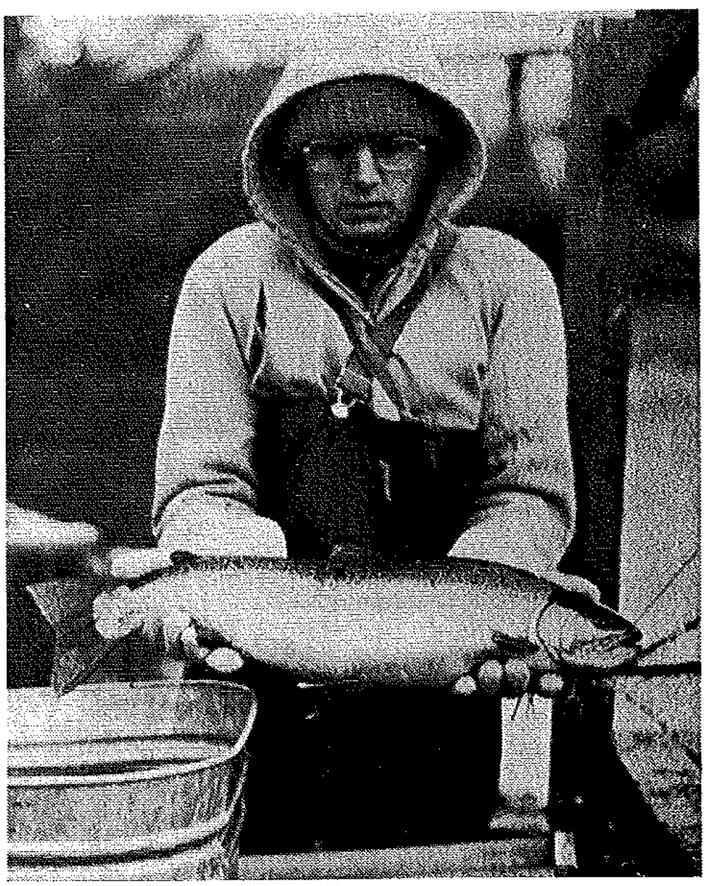
TABLE 14. Mean length (inches) of brown and rainbow trout captured at the Hwy. 2 weir (upstream migrants) and by electrofishing.

	Hwy. 2 Weir			Electrofishing
Time Period	Males	Females	Overall	Overall
Brown Trout				
Fall 1978	--	--	21.6 (615)	--
Fall 1979	22.7 (717)*	21.4 (587)	22.1 (1,304)	22.0 (61)
Rainbow Trout				
Fall 1978	--	--	23.4 (141)	23.4 (164)
Spring 1979	25.3 (698)	25.3 (1,207)	25.3 (1,905)	--
Fall 1979	--	--	24.2 (126)	23.7 (265)
Spring 1980	25.2 (646)	25.4 (833)	25.3 (1479)	--

*Sample size.



The average size of migratory brown trout in the spawning run was approximately 22 inches and 4 lbs.



The average size of rainbow trout in the spawning run was approximately 25 inches and 6 lbs.

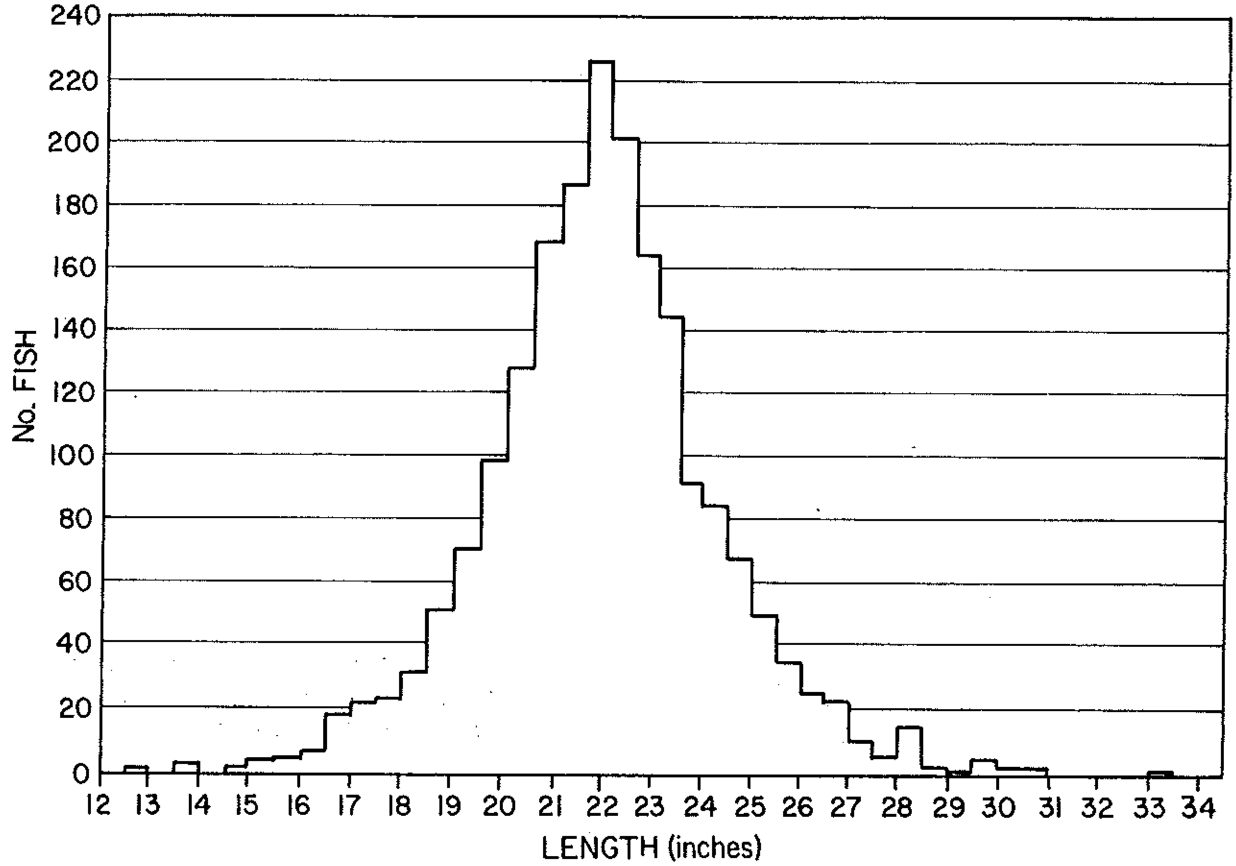


FIGURE 5. Length frequency of brown trout (sexes combined) captured at the Hwy. 2 weir and by electrofishing (July 1978-November 1979).

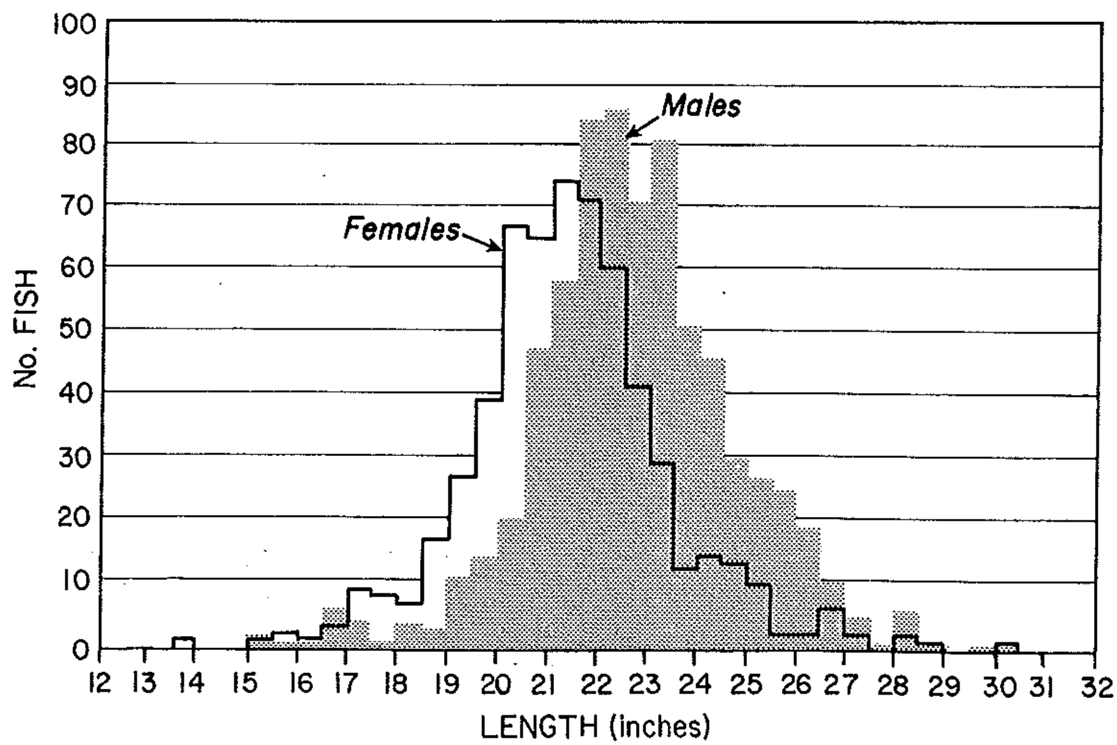


FIGURE 6. Length frequency by sexes of brown trout captured at the Hwy. 2 weir and by electrofishing (July 1978-November 1979).

Rainbow trout in the spring upstream weir catches ranged in length between 13.5 and 32.4 inches, with a modal peak between 26.0 and 26.4 inches (Fig. 7). The mode of the length frequency for males was slightly larger than for females (Fig. 8); however, mean lengths did not differ between sexes.

Weight-Length Relationship

Weight-length relationships for brown and rainbow trout were expressed using a power curve, represented by the equation:

$$W = bL^{m} \qquad (1)$$

or:

$$\log W = \log b + m(\log L) \qquad (2)$$

where:
W = weight in pounds
L = length in inches
b = y-intercept (constant)
m = slope (constant)

The slopes of the regressions of log transformed data were significantly different from 0 at the $P < 0.01$ level in all of the following weight-length relationships.

The weight-length relationship for upstream migrating (pre-spawn) brown trout, sexes combined, was expressed by:

$$W = .00052\ L^{2.89988} \qquad (3)$$

with coefficient of correlation $\underline{r} = 0.93$ and sample size N = 100.

Downstream migrating (spawned out) brown trout (sexes combined) during spring show a weight-length relationship expressed by:

$$W = .00017\ L^{3.19064} \qquad (4)$$

with $\underline{r} = 0.93$ and N = 50. Brown trout show considerable weight loss during the time between pre-spawn migration in late summer and fall, and downstream migration in spring (Table 15). Percent weight loss decreases with an increase in length of brown trout. The loss of body fat during winter may amount to a larger proportion of total body weight for small brown trout than for larger ones.

Male and female rainbow trout prior to spawning showed nearly identical weight-length relationships, expressed by the equations that follow for males:

$$W = .00074\ L^{2.79248} \qquad (5)$$

with $\underline{r} = 0.84$ and N = 100, and for females:

$$W = .00075\ L^{2.78982} \qquad (6)$$

with $\underline{r} = 0.92$ and N = 100.

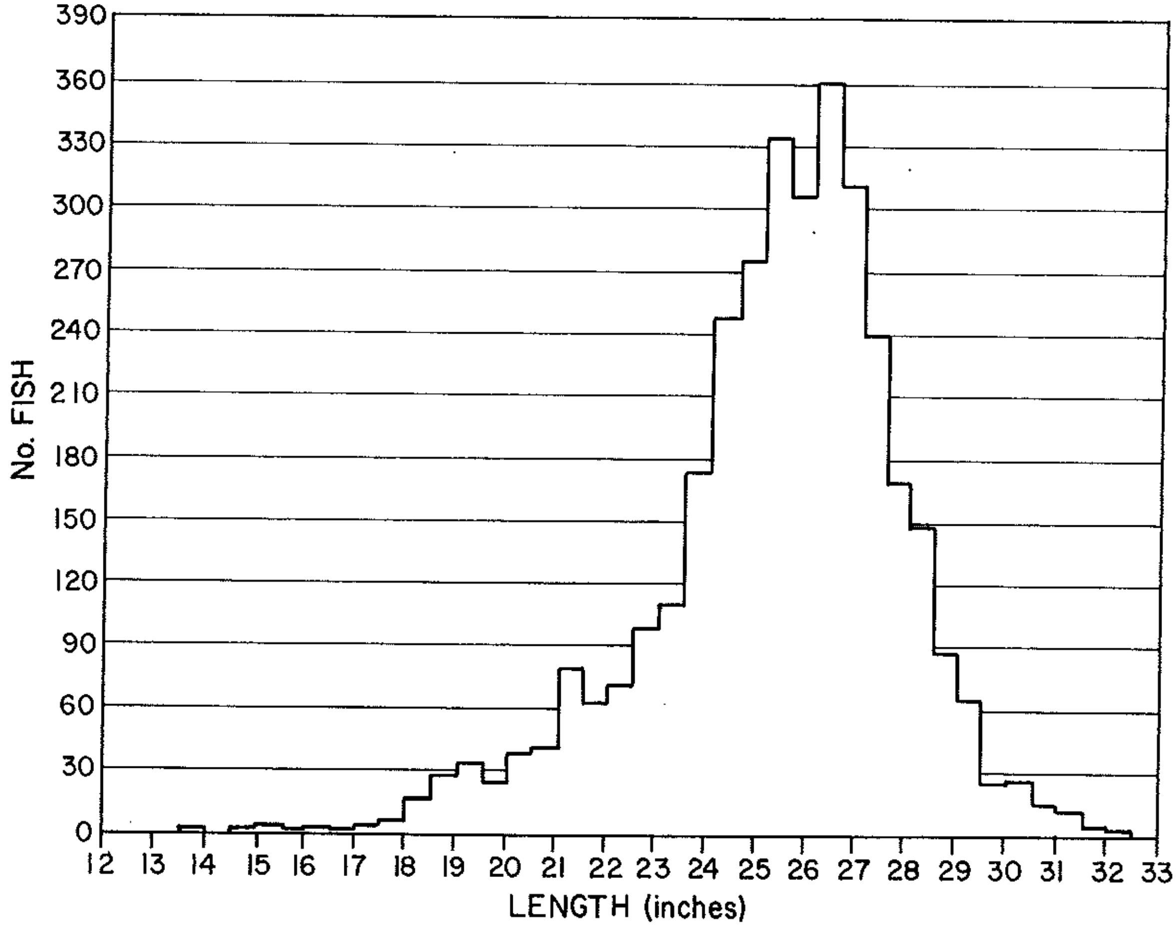


FIGURE 7. Length frequency of rainbow trout (sexes combined) captured at the Hwy. 2 weir (spring 1979 and 1980).

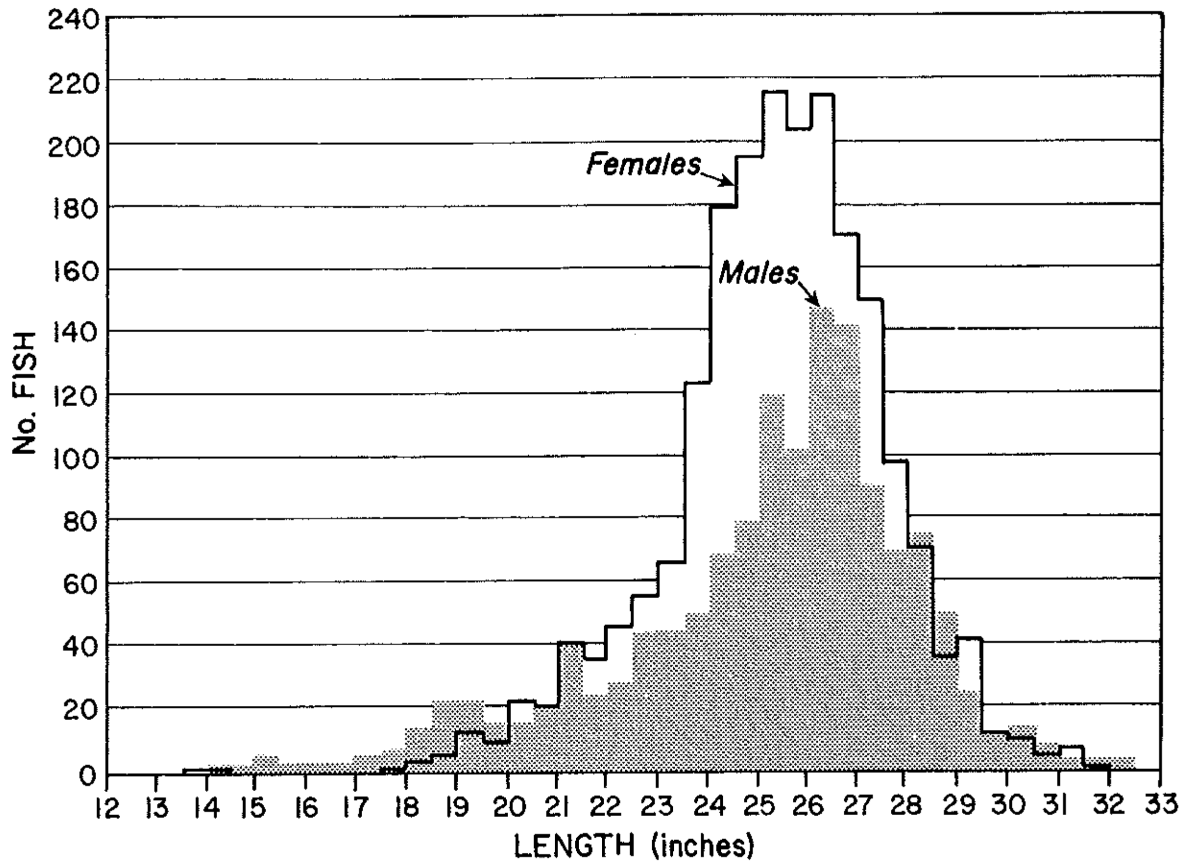


FIGURE 8. Length frequency by sexes of rainbow trout captured at the Hwy. 2 weir (spring 1979 and 1980).

Pre-spawn average weights of rainbow trout based on equations 5 and 6 were identical for both sexes less than 25 inches in length; for fish 25 inches and larger, males averaged 0.1 lb lighter. Post-spawn weights for males averaged 0.1 lb heavier than females for fish over 16 inches. Unlike the brown trout, percent weight loss during the spawning period increased with an increase in length of rainbow trout (Table 16).

TABLE 15. Average weights of pre-spawn (summer and fall) and post-spawn (spring) brown trout, and percent weight loss.

Length (inches)	Pre-spawn Weight (lb)	Post-spawn Weight (lb)	Weight Loss (%)
15	1.3	1.0	23
16	1.6	1.2	25
17	1.9	1.4	26
18	2.3	1.7	26
19	2.7	2.0	26
20	3.1	2.4	23
21	3.6	2.8	22
22	4.1	3.3	20
23	4.6	3.8	17
24	5.2	4.3	17
25	5.9	4.9	17
26	6.6	5.6	15
27	7.4	6.3	15
28	8.2	7.0	15
29	9.1	7.9	13
30	10.0	8.8	12
31	11.0	9.7	12
32	12.0	10.8	10
33	13.2	11.9	10

TABLE 16. Average weights of pre-spawn and post-spawn female rainbow trout during spring, and percent weight loss.

Length (inches)	Pre-spawn Weight (lb)	Post-spawn Weight (lb)	Weight Loss (%)
15	1.4	1.4	0
16	1.7	1.7	0
17	2.0	1.9	5
18	2.4	2.2	8
19	2.8	2.6	7
20	3.2	2.9	9
21	3.7	3.3	11
22	4.2	3.7	12
23	4.7	4.1	13
24	5.3	4.6	13
25	6.0	5.1	15
26	6.7	5.6	16
27	7.4	6.2	16
28	8.2	6.8	17
29	9.1	7.4	19
30	10.0	8.1	19
31	10.9	8.8	19
32	11.9	9.5	20
33	13.0	10.3	21

AGE AND GROWTH

Age Frequency

A total of 227 upstream migrant brown trout were aged ranging from age II to age IX, with the highest percentage (53%) being age IV (Table 17). Brown trout populations during the early 1960's (Niemuth 1967) showed a similar age structure but lacked fish older than age VI. Ages of brown trout from both studies were based on number of annuli present on a scale; however, browns at time of capture in the fall had an additional summer's growth since formation of the last annulus. For practical purposes, these trout might be considered a year older as annual growth was likely near completion at the time of capture.

The three most abundant age groups of brown trout in the 1978 and 1979 spawning runs (ages III, IV, and V) would correspond to the 1973, 1974, 1975, and 1976 year classes. The only brown trout stocking that was done in the Brule River during any of these years was a plant of 6,000 yearling brown trout in 1974. The dominant year classes in the 1978 and 1979 spawning runs appeared, therefore, to be a result of natural reproduction and not stocking.

Scales were collected from rainbow trout during spring just prior to annulus formation, so the outer scale margin was counted as an annulus. A total of 626 upstream migrant rainbows were aged ranging from age III to age X (Table 17). Highest percentages were age V (39%) and age VI (30%). Data from the early 1960's (Niemuth 1970) showed a lack of fish age VI and older. Niemuth had a much higher percentage of age III fish, which was probably a result of smaller spaced openings on the 1961 weir allowing capture of smaller rainbows in the 11- to 15-inch range.

TABLE 17. Percent of brown and rainbow trout of each age collected at the Hwy. 2 weir and the Brule River mouth during the early 1960's (Niemuth 1967, 1970) and the present study.

Species	Time Period	II	III	IV	V	VI	VII	VIII	IX	X
Brown trout	1961-64	0	30	52	17	1				
	1978-79	1	37	53	5	1	1	0	1	
Rainbow trout	1961-64	0	31*	27	34	7	1			
	1979-80	0	4	13	39	30	10	3	1	1

*High percentage of age III rainbows during earlier study likely a result of smaller spaced openings on 1961 weir.

The two most abundant age groups in the 1979 and 1980 rainbow trout runs (ages V and VI) would correspond to the 1973, 1974, and 1975 year classes. Rainbow trout stocking in the Brule River during these years was as follows: 1973--20,000 yearlings, 753 adults (13 inches); 1974--4,000 yearlings; 1975--3,500 yearlings. Except for 1973, these were relatively small plants; and even the 1973 plant could at most account for only a portion of the 6-year olds. We believe, therefore, that the dominant year classes in the 1979 and 1980 rainbow trout runs were, like brown trout, not the result of stocking but of natural reproduction.

Length frequencies by age group showed considerable overlap in length between different ages in brown (Table 18) and rainbow trout (Table 19). In the case of rainbow trout, fish of the same age could vary as much as 13 inches in length and fish of the same inch group could vary as much as 6 years in age.

TABLE 18. Age distribution by length group for upstream migrant brown trout captured during fall 1978 and 1979.

Length group (inches)	No. in Interval	Number Per Age Group II	III	IV	V	VI	VII	VIII	IX
16	2			2					
17	11	1	6	4					
18	13	1	8	4					
19	27		17	8	2				
20	35		16	18	1				
21	60	1	27	31	1				
22	30		7	22	1				
23	19		1	13	5				
24	9			9					
25	10			8	1		1		
26	2			1		1			
27	1				1				
28	1					1			
29	2						2		
30	1								1
31	0								
32	0								
33	1								1

TABLE 19. Age distribution by length group for upstream migrant rainbow trout captured during spring 1979.

Length group (inches)	No. in Interval	Number Per Age Group III	IV	V	VI	VII	VIII	IX	X
12	1	1							
13	0								
14	4	3	1						
15	12	12							
16	5	3	2						
17	8	4	3	1					
18	10	1	9						
19	9		8	1					
20	12		8	2	2				
21	27	1	15	8	3				
22	28		14	11	3				
23	54		10	30	13	1			
24	94		9	58	22	5			
25	116		1	67	40	8			
26	120			49	54	12	5		
27	69			14	29	17	7	2	
28	36			3	14	13	3	2	1
29	15			1	3	3	6	1	1
30	4				3	1			
31	2					1		1	
32	1					1			

Aging of smolts captured at the electric lamprey weir revealed two age classes of brown trout smolts and three age classes of rainbow smolts. Brown trout smolts were predominantly (86%) age II fish ranging between 5.5 and 8.5 inches, with age I smolts (14%) between 4.5 and 5.5 inches (Fig. 9). Mean lengths for age I and II brown smolts were 5.2 and 7.3 inches, respectively, at time of capture in late June and early July. Rainbow trout smolts of ages I, II, and III averaged 5.2, 7.3, and 8.9 inches, respectively, and ranged collectively between 4.5 and 10.5 inches (Fig. 10). Age I smolts predominated (59%), with 38% age II and 3% age III.

Ages of rainbow trout smolts were in general agreement with Stauffer (1972) who found that in a Lake Michigan tributary (Black River), 68% of the rainbows migrated downstream at age I, 31% at age II, and 1% at age III.

Years of stream life (parr years) were also determined from scales of adult fish. Annuli formed while a fish was in the stream were closely spaced toward the scale focus. During the season when a trout migrated downstream to the lake, a check was formed on the scale, presumably at the time the fish

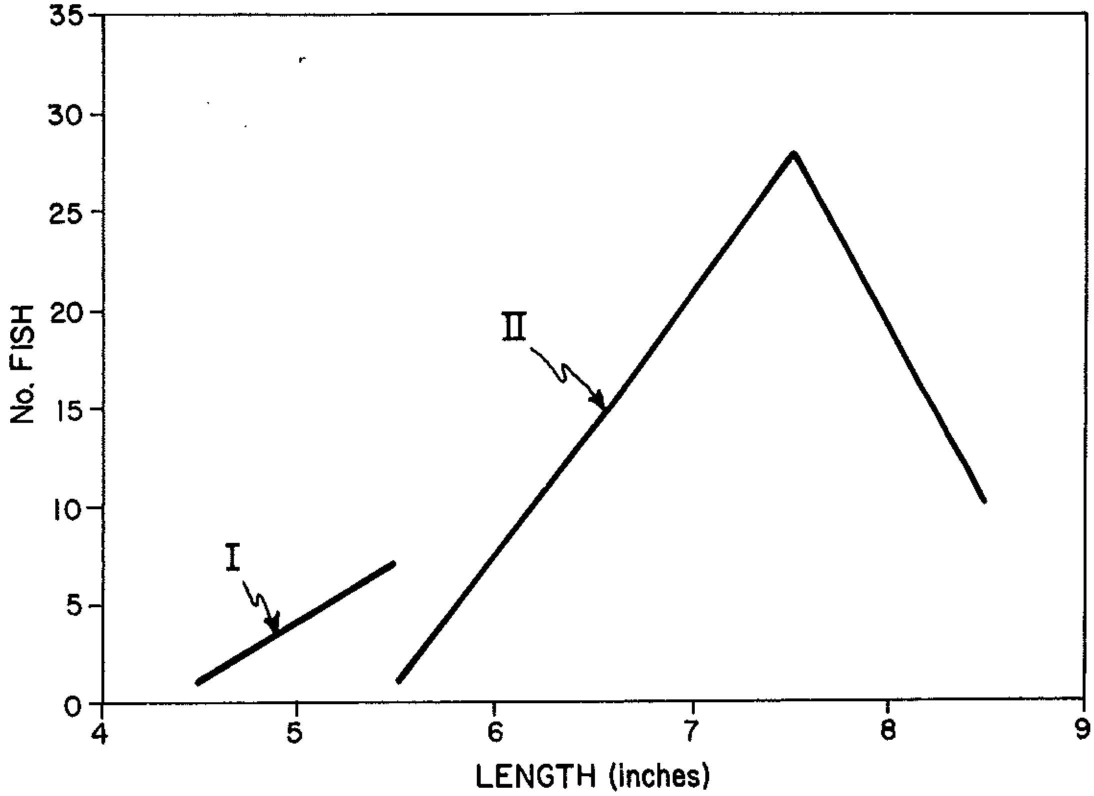


FIGURE 9. Length frequency by age class of brown trout smolts captured at the electric lamprey weir (June 21-July 6, 1979).

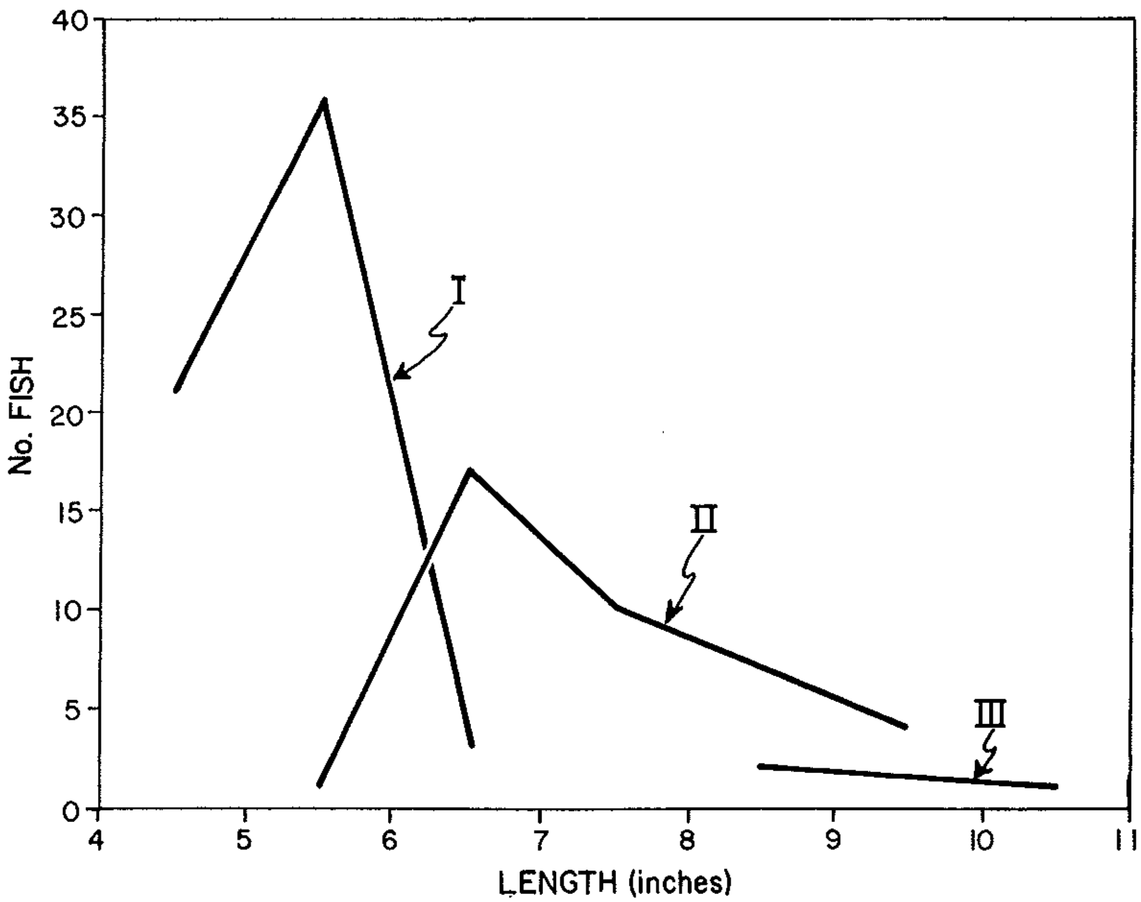


FIGURE 10. Length frequency by age class of rainbow trout smolts captured at the electric lamprey weir (June 21-July 6, 1979).

commenced feeding in the lake. Scale circuli were spaced wider after the "migration check", and the next year's annulus was widely separated from previous annuli.

Based on number of stream annuli on scales from adult trout, most browns migrated downstream at age II (Table 20), in agreement with ages based on smolt scales. Although percentages differ slightly between smolts and adults, the pattern remains the same. Numbers of stream annuli on scales from adult rainbow trout however, showed that most of these fish (87%) had spent 2 years in the river, as opposed to a majority of 1-year-olds, when based on smolt scales (Table 20).

Apparently, large numbers of age I rainbows suffered differential mortality between the time they migrated to the lake and the time they returned to spawn; hence a majority of spawners had 2 years of stream life. Perhaps these small age I trout were being outcompeted by larger trout for available food or cover in the upstream areas, and were being prematurely forced downstream into less desirable areas in the lower river and Lake Superior where they were subject to heavier predation. The lower Brule River near the mouth is inhabited by several large predators, including northern pike, walleye, and muskellunge, in addition to the large migratory trout and salmon which pass through.

Other workers have noted differences in migration ages of rainbow trout based on scales from smolts and adults. Kwain (1971) found 38%, 58%, and 4% of the adult rainbow trout in Batchawana Bay, Lake Superior, had spent 1, 2, and 3 years, respectively, in the stream. Similarly, Kwain (1981) found that of adult rainbow trout in Stokely Creek (tributary to Batchawana Bay), 41%, 53%, and 6% had spent 1, 2, and 3 years, respectively, in the stream; however, of downstream migrating smolts in Stokely Creek, 76% had spent only 1 year in the stream, 23% had spent 2 years, and 1% had spent 3 years. Stauffer (1972) summarized findings by several authors (Greeley 1933, Reynolds 1947, Shetter 1965, Dodge and MacCrimmon 1970) and found that 10% of Great Lakes adult rainbow trout had one stream annulus, 86% had two, and 4% had three. Stauffer

TABLE 20. Percentages of brown and rainbow trout having spent 1, 2, or 3 years in the river prior to downstream migration, based on scales from smolts and from adults.

Years of	Brown Trout		Rainbow Trout	
Stream Life	% of Smolts	% of Adults	% of Smolts	% of Adults
1	14 (8)*	36 (81)	59 (61)	3 (17)
2	86 (51)	63 (142)	38 (39)	87 (543)
3	0 (0)	2 (4)	3 (3)	11 (66)

*Sample size.

noted that cursory inspection of adult rainbow trout scales from the Black River, Michigan also suggested that more juveniles migrated at age II than at age I, in spite of opposite findings based on smolt scales.

Kwain (1971) noted that there was an inverse relation between size at a given age and duration of stream life; and suggested that it may be desirable to encourage the establishment of stocks having only a brief stream residency, as fish with only 1 year of stream life mature rapidly and appear in the spawning population at a younger age. Kwain (1981) mentioned that if a stream supports a given weight of 1-year-old smolts, an equal weight of older smolts would require more space, which would decrease the number, and be less efficient in food conversion. Since survival of age I smolts appears poor in the lower Brule River sections and in Lake Superior, however, it may actually be more desirable to encourage longer stream residencies. Only small percentages of rainbow trout were found to have migrated downstream at age III from any of the above sources, but we suspect those few that do may have a better chance for survival due to their slightly larger size. Hassinger et al. (1974), in a study of rainbow trout in two Minnesota tributaries to Lake Superior, found that the older, larger emigrants returned as larger fish and in far greater numbers than did younger emigrants, due to their apparently better survival. The encouragement of rainbow trout stocks with only a brief stream residency might ultimately reduce average size of fish in the spawning population and lessen the "trophy" value of a fishery, an important consideration on the Brule River.

Growth in Length

The body-scale relation for brown trout was described by the equation:

$$L = 1.26 + 0.16S \qquad (9)$$

where L = total length in inches
and S = anterior scale radius (millimeters X 42.6)

The body-scale relation for rainbow trout was described by the equation:

$$L = 0.47 + 0.19S \qquad (10)$$

Coefficient of correlation $r = 0.99$ for both formulas and slopes of the regressions were significantly different from 0 at the $P < 0.01$ level.

These body-scale relations were based only on data from scales of downstream migrant smolts, because of differences in slopes of the regressions between smolts and adults. The regressions appear valid for back-calculation of lengths since their intercepts more realistically approximate fish lengths at time of scale formation than do regressions from either adult scales or combined data. Back-calculated lengths from scales of adult trout are similar to back-calculated lengths from rainbow trout smolts (Table 21) and brown trout smolts (Table 22) at same ages, which indicates that valid back-calculations can be made from these regressions.

Total length at the end of each year of life was back-calculated for 227 upstream migrant brown trout collected during 1978 and 1979(Table 23), and

TABLE 21. Backcalculated lengths at previous annuli from scales of rainbow trout smolts of different ages compared with backcalculated lengths at same ages from scales of adult rainbows (in parentheses).

Smolt Age	Number in Sample	Age Group I	Age Group II	Age Group III
I	61 (17)	3.5 (3.5)	--	--
II	39 (543)	2.7 (2.9)	6.3 (6.3)	--
III	3 (66)	2.8 (2.6)	5.1 (5.5)	8.0 (8.6)

TABLE 22. Backcalculated lengths at previous annuli from scales of brown trout smolts of different ages compared with backcalculated lengths at same ages from scales of adult browns (in parentheses).

Smolt Age	Number in Sample	Age Group I	Age Group II
I	8 (81)	3.9 (4.6)	--
II	51 (142)	3.2 (3.8)	6.5 (7.4)

626 upstream migrant rainbow trout captured during spring, 1979 (Table 24). Weighted average lengths indicate that patterns and rates are similar for brown trout (Table 25) and rainbow trout (Table 26). Length at a given age is greater for trout having the fewest years of stream residency, but growth of brown and rainbow trout with 2 years stream life seems to "catch up" with growth of trout with 1 year stream life by the end of the 5th or 6th year (Figs. 11 and 12). Lengths of trout with 3 years of stream life do not equal lengths of trout with fewer stream years at any point in life.

Average annual growth increment for brown trout decreases each year for fish that remain in the river more than 1 year (Table 25, Fig. 13). Largest increment was during the first year of life in Lake Superior, and decreased again each year thereafter.

Annual length increment for rainbow trout, unlike brown trout, increased slightly during each year of stream life for those fish that did not migrate to Lake Superior at age I (Table 26, Fig. 14). Salli (1962) found that a large percentage of the year's growth by juvenile rainbow trout in the Brule River was completed early in the summer. YOY (age 0) rainbow trout completed 59% of the year's growth by mid-July, while age I trout completed 76% to 86% and age II trout completed 78% to 80% of the annual length increment by mid-July.

The pattern of growth increments once rainbow trout enter Lake Superior was similar to that of brown trout. For both species, the magnitude of the increment during the first year of lake life was greatest for fish with fewest years of stream life.

Little published information is available on age and growth of other migratory brown trout stocks in the Great Lakes. Unpublished data from DNR-Bayfield show growth of brown trout taken by various methods in western Lake Superior from 1967 through 1969 was very similar to growth of Brule River migratory brown trout in the present study.

Growth rates of Brule River rainbow trout were similar to those of rainbow trout in Minnesota tributaries of Lake Superior (Hassinger et al. 1974) and in the Nottawasaga River, an Ontario tributary to Lake Huron (Wainio 1962). Great Lakes rainbow trout in general were much slower growing than those of the Pacific coastal region. Steelheads with two years of stream life in the Chilliwack River, British Columbia, attain fork lengths of 18.7, 27.5, 31.9, and 38.0 inches at ages III, IV, V, and VI respectively (Maher and Larkin 1955).

TABLE 23. Mean calculated total lengths at end of each year of life for brown trout collected during late summer and fall 1978 and 1979 (last lengths in each horizontal row represent empirical lengths at time of capture, not at time of annulus formation).

Age Group	No. Years Stream Life	Number of Fish	Calculated length (inches) at End of Year of Life									
			1	2	3	4	5	6	7	8	9	10
II	1	2	5.5	15.5	19.2							
	2	1	3.9	8.6	18.4							
III	1	62	4.6	13.2	19.1	20.8						
	2	22	4.2	8.7	16.5	19.1						
IV	1	15	4.8	11.3	16.3	21.2	22.8					
	2	104	4.0	7.6	14.1	20.1	21.9					
	3	2	3.7	7.0	9.8	14.6	16.5					
V	1	2	4.5	12.1	15.0	20.7	22.6	23.8				
	2	8	3.7	7.4	13.5	18.3	21.5	23.1				
	3	2	3.4	6.9	8.8	14.2	18.6	20.0				
VI	2	2	3.5	7.2	11.8	18.6	23.7	25.8	27.1			
VII	2	3	4.1	7.2	13.8	19.7	32.2	25.2	26.8	28.1		
VIII	-	-	-	-	-	-	-	-	-	-	-	-
IX	2	2	4.0	7.5	11.9	17.5	22.0	24.7	27.0	29.2	30.8	32.0

TABLE 24. Mean calculated total lengths at end of each year of life for rainbow trout collected during spring 1979 (last lengths in each horizontal row represent empirical lengths just prior to annulus formation).

Age Group	No. Years Stream Life	Number of Fish	Calculated Length (inches) at End of Year of Life									
			1	2	3	4	5	6	7	8	9	10
III	1	2	3.2	12.6	18.4							
	2	23	2.9	6.1	15.7							
	3	0	-	-	-							
IV	1	3	4.0	13.5	20.2	24.4						
	2	73	3.1	7.0	16.9	21.3						
	3	4	2.7	6.0	9.6	17.9						
V	1	9	3.6	13.8	20.4	24.2	26.4					
	2	226	3.0	6.4	16.2	21.9	25.0					
	3	9	2.9	6.1	9.9	18.6	22.6					
VI	1	1	4.3	10.7	15.6	20.0	22.6	24.9				
	2	159	2.8	6.1	15.3	21.0	24.1	26.3				
	3	26	2.6	5.7	8.6	17.1	22.6	25.2				
VII	1	2	3.5	13.8	19.7	21.9	24.0	25.5	27.0			
	2	39	2.8	6.1	15.6	20.8	23.7	25.7	27.4			
	3	21	2.5	5.1	8.1	16.2	22.0	24.7	26.6			
VIII	1	0	-	-	-	-	-	-	-	-		
	2	16	2.6	5.8	14.3	19.5	22.3	24.7	26.4	28.0		
	3	5	2.6	5.0	7.4	15.7	20.0	23.2	25.9	27.5		
IX	1	0	-	-	-	-	-	-	-	-	-	
	2	6	2.8	5.6	15.0	18.5	21.3	23.9	25.8	27.2	28.7	
	3	0	-	-	-	-	-	-	-	-	-	
X	1	0	-	-	-	-	-	-	-	-	-	-
	2	1	2.8	6.0	15.3	21.0	23.0	25.0	26.7	27.6	28.5	29.3
	3	1	2.0	4.6	7.8	12.6	15.8	18.7	22.1	24.6	26.4	28.2

TABLE 25. Weighted average lengths and average annual growth increment for brown trout collected as adults in the Brule River during fall 1978 and 1979.

	No. Years Stream Life	Number of Fish	Length or Growth (inches) at End of Year of Life								
			1	2	3	4	5	6	7	8	9
Weighted average lengths	1	81	4.6	12.9	18.5	21.1	22.6				
	2	142	3.8	7.4	14.4	19.9	22.2	25.2	26.9	29.2	30.8
	3	4	3.5	7.0	9.3	14.4	18.6				
Average annual growth increment	1	81	4.6	8.2	5.7	5.0	1.9				
	2	142	3.8	3.6	6.6	5.9	3.7	2.2	1.9	2.2	1.6
	3	4	3.5	3.4	2.4	5.1	4.4				

TABLE 26. Weighted average lengths and average annual growth increment for rainbow trout collected as adults in the Brule River during spring 1979.

	No. Years Stream Life	Number of Fish	Length or Growth (inches) at End of Year of Life									
			1	2	3	4	5	6	7	8	9	10
Weighted average lengths	1	17	3.5	13.4	19.8	23.7	25.7	25.3	27.0			
	2	543	2.9	6.3	15.9	21.3	24.4	26.0	27.0	27.8	28.7	29.3
	3	66	2.6	5.5	8.6	16.9	22.1	24.7	26.3	27.0	26.4	28.2
Average annual growth increment	1	17	3.5	9.8	6.3	3.7	2.2	1.8	1.5			
	2	543	2.9	3.4	9.6	5.4	3.1	2.2	1.7	1.6	1.4	0.9
	3	66	2.6	2.9	3.1	8.3	5.2	2.7	2.1	1.8	1.8	1.8

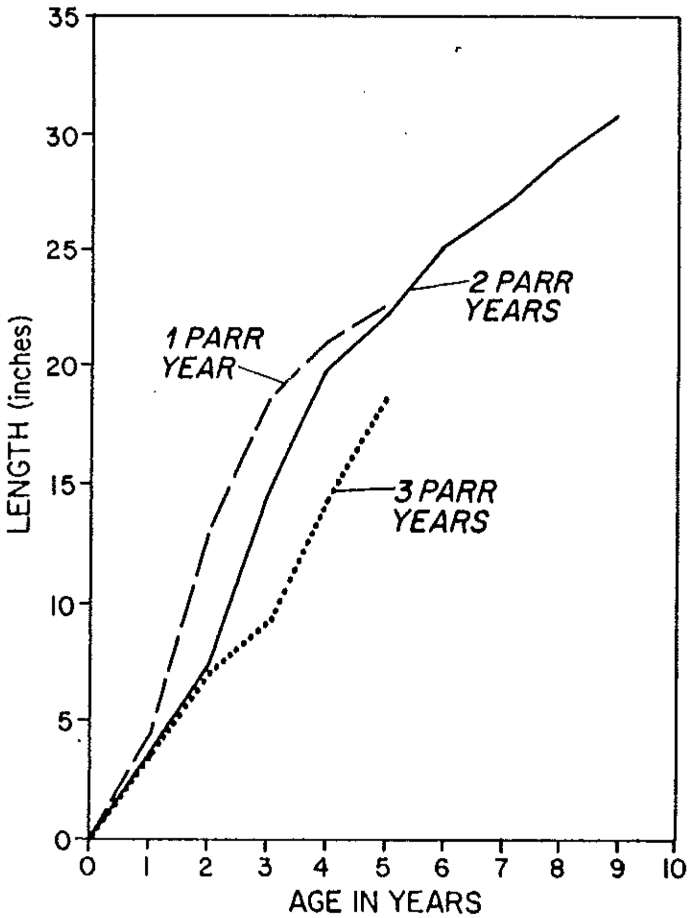


FIGURE 11. Growth curves for brown trout by number of years of stream life (parr years), based on weighted average lengths at end of each year of life.

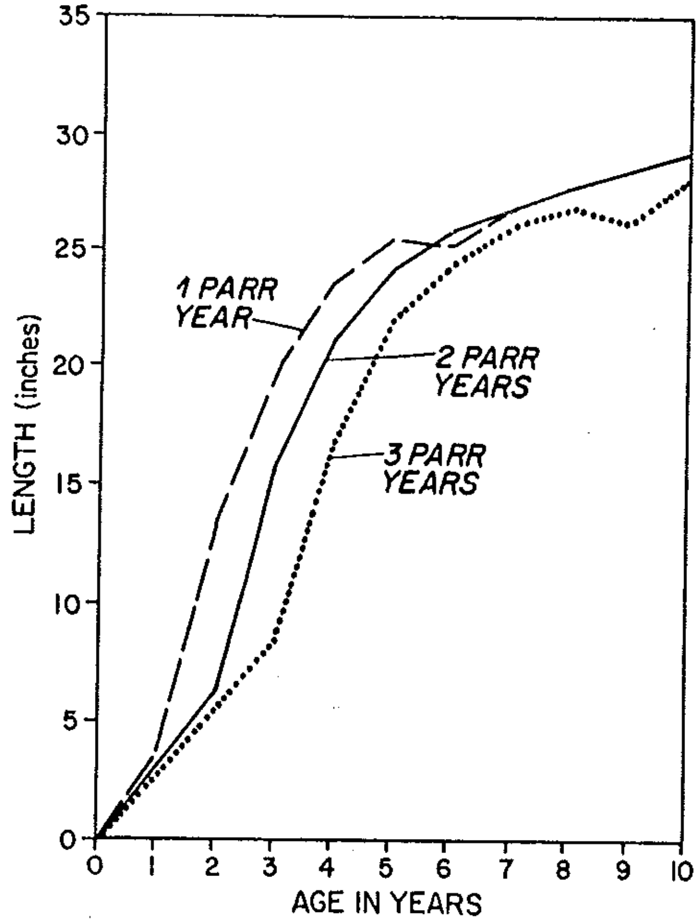


FIGURE 12. Growth curves for rainbow trout by number of years of stream life (parr years), based on weighted average lengths at end of each year of life.

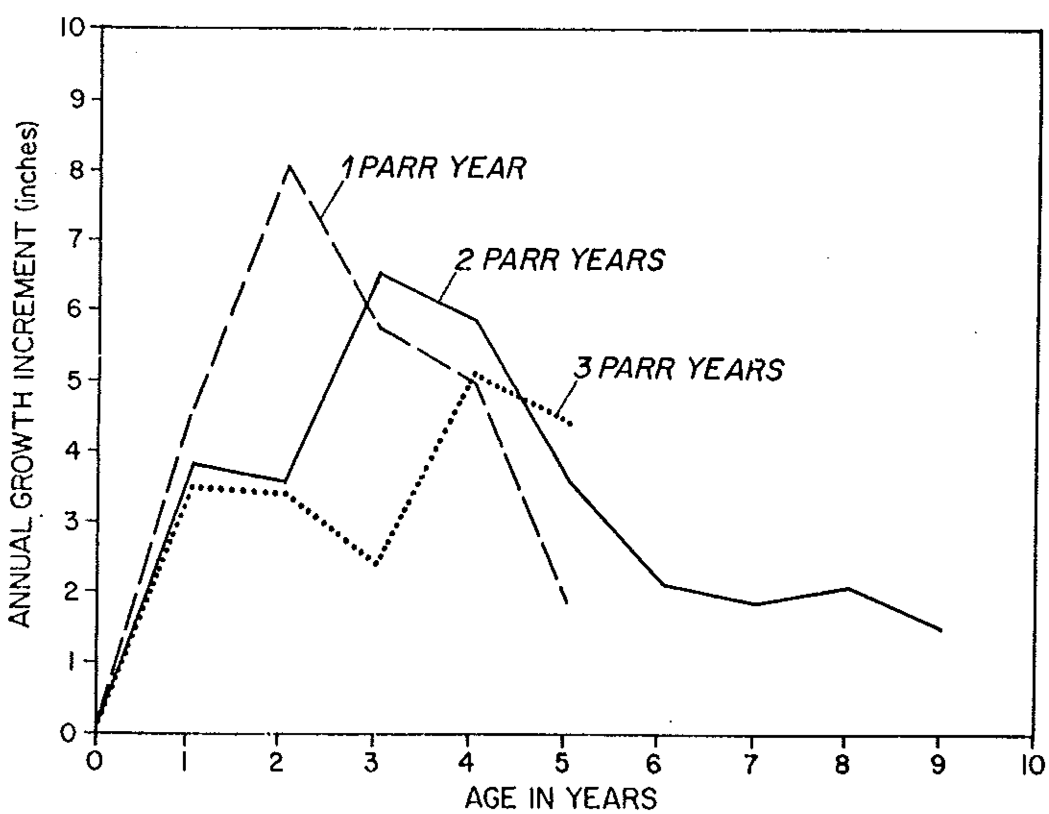


FIGURE 13. Mean annual growth increments for brown trout by number of years of stream life (parr years).

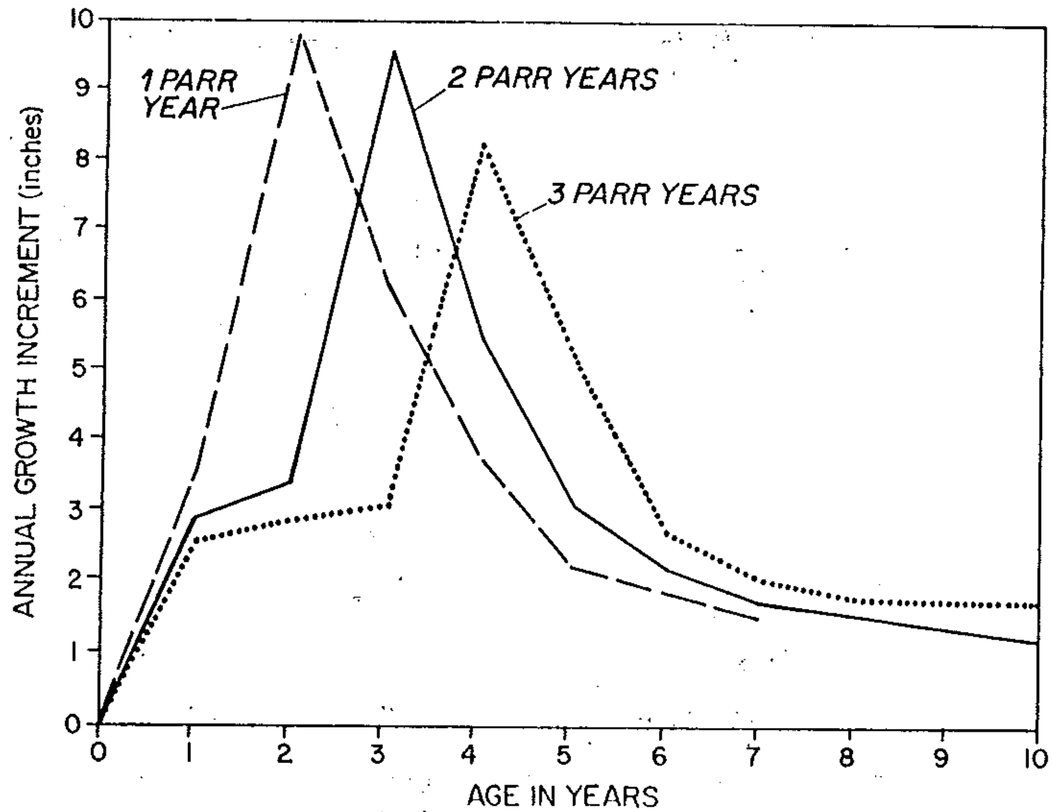


FIGURE 14. Mean annual growth increments for rainbow trout by number of years of stream life (parr years).

INJURIES AND ABNORMALITIES

In general, brown trout showed a higher incidence of infectious diseases (furunculosis, Saprolegnia sp.) than rainbow trout, whereas rainbow trout appeared more prone to various physical injuries and deformities (Table 27). Externally observed spinal deformities were more prevalent in rainbow trout (3.4 - 5.4%) than in brown trout (0 - 0.8%). We believe that many of these spinal deformities were the result of injuries received while passing through the electrical field of the U.S. Fish and Wildlife Service sea lamprey weir. This weir was operated from 1957 through 1979, beginning each year in early April and ending near July 15. Studies by DeVore and Eaton (1983) found a much higher incidence of spinal deformity in Brule River trout, and support the probability that injuries were caused by the electric weir. They found that incidence of spinal deformity in externally examined and x-rayed migratory rainbow trout was 26% and 50%, respectively, while lake-run brown trout had an incidence of 8% and 16%, respectively. No vertebral abnormalities were found in 75 Brule River juvenile rainbow trout, nor in 25 lake-run rainbow trout from the French River, Minnesota.

Differences in incidence of spinal deformity between the two species may be related to time of peak downstream migration by smolts of the two species. Peak downstream migration of rainbow trout occurred during June, both in the Brule River (Table 13) and in Black River, Michigan (Stauffer 1972). Brown trout smolt migration in the Brule River also peaked during June, but Niemuth (1967) found another peak in migration during August and September at the Hwy. 2 weir. Whether there was significant migration of brown trout smolts during August and September further downstream is unknown, but it is possible that many brown trout migrated through the electric weir after it was turned off in mid-July and avoided injury.

The electric weir was permanently dismantled in July 1979. If this weir was a primary cause of spinal injuries, there should be a noticeable decrease in the incidence of deformed backbones within a few years.

Lamprey scars did not occur on more than 1.5% of the total trout captured during any period, and were no more prevalent in either species. The occurrence of lamprey scarring in Brule River brown trout decreased each year from 14.8% in 1961 to 1.8% in 1964, following the initial years of chemical lamprey control in Lake Superior tributaries (Niemuth 1967). Only a small percentage (approximately 1%) of rainbow trout captured during the early 1960's bore lamprey scars (Niemuth 1970). This relatively low incidence of scarring compared to that of brown trout may be explained at least in part by the large percentage of small (age II) rainbow trout captured. The smaller trout may have been less vulnerable to attack by sea lampreys because of the lamprey's preference for larger trout, or because they were available to lampreys for a shorter period; and/or they may have been less likely to survive and bear scars if they were attacked.

Gill net scars were evident on a very small number (0.2% or less) of brown and rainbow trout. These were evident as a ring-like mark or constriction around the body just posterior to the head.

Injuries and deformities of the jaws or mouth were most common in rainbow trout. Many of these injuries, particularly on upstream migrants, were attributed to hooking by anglers. Many downstream migrants after spawning had jaw injuries, presumably from the rigors of spawning and fighting on the spawning areas. The majority of these fish were males. Some males had their lower jaws completely broken and hanging freely.

TABLE 27. Percent of brown and rainbow trout with abnormalities.

Abnormality	Brown Trout Fall Up* (1,260)[1]	Brown Trout Fall Down** (83)	Rainbow Trout Fall Up (386)	Rainbow Trout Spring Up (3,183)	Rainbow Trout Spring Down (570)
Spinal deformity	0.8	0.0	3.4	4.9	5.4
Lamprey scar	1.5	0.0	0.3	1.3	1.4
Gillnet scar	0.2	0.0	0.0	<0.1	0.2
Jaw injury or deformity	1.7	1.2	3.9	6.1	9.1
Fin injury or deformity	2.5	2.4	2.3	3.3	16.7
Eye injury	<0.1	0.0	0.0	0.4	0.7
Misc. scars, injuries and deformities	11.2	1.2	1.8	4.0	13.3
Fungus infection	2.3	8.4	0.8	0.3	17.4
Furunculosis symptoms	0.7	6.0	0.0	0.0	0.0

*Upstream migrants.
**Downstream migrants.
[1]Sample size.

Injuries to fins, eyes and other areas of the body were most prevalent in post-spawn rainbow trout, as was fungus (Saprolegnia sp.) infection. The physical act of redd building by spawning trout likely results in a great deal of erosion and injury to the fins and body. Fungus is considered a secondary invader on fish that already have a disease, physical injury, or that have lost their protective slime coating; particularly if the fish have been weakened by stresses (Allison et al. 1977). An infected fish may recover when it returns to its normal environment and resumes normal feeding habits, provided the original disease or injury does not eventually prove fatal.

Various physical injuries were more prevalent in downstream migrant rainbow trout in 1980 than in 1979. Percentages of fish with jaw injuries in 1979 and 1980 were 5.8% and 13.5%, respectively. Percentages of downstream migrants with fin injuries were 12.9% and 21.7%, respectively, in 1979 and 1980. There was also a higher incidence of fungus infection concurrent with the large number of injuries in 1980. River level was extremely low during spring of 1980. There may have been fewer spawning areas with an optimum water depth over the substrate, which could have resulted in more fighting and competition for the preferred spawning areas that were available. Spawning areas may not be limiting to reproduction and recruitment, but they may be limiting to the number of spawners trying to occupy them at a given time.

The percentages of brown trout captured that had symptoms of furunculosis were deceivingly low, because a great number of fish that became infected died within a short time and were recovered dead, or were not recovered at all. (See discussion under Natural Mortality.)

Furunculosis, or "red spot", is a disease caused by the bacterium *Aeromonas salmonicida*, that has been common in the Brule system as well as in other Lake Superior tributaries for many years. The disease was first positively identified in the Brule River in 1956 by DNR personnel. Furunculosis has frequently reached epidemic proportions in the Brule River.

Brown trout appear to be most susceptible to furunculosis, although the other trout species can contract the disease (Davis 1956, Allison et al. 1977). Rainbow trout are considered relatively immune to furunculosis; however, we obtained positive bacterial cultures of the disease from two dead adult rainbow trout during fall 1979. Positive cultures were also obtained from two dead brook trout and a lake trout.

Furunculosis affects all parts of the body, but the extent of the symptoms depends upon how quickly the fish dies after becoming infected. External symptoms include open sores and large, watery "boils"; but a fish that is quickly overcome by the disease may die before it shows any external symptoms. Internal symptoms include inflammation of the intestines and kidney, and hemorrhaging of the internal tissues.

MORTALITY

Natural Mortality

Furunculosis undoubtedly accounts for most of the natural mortality occurring in the migratory brown trout population during the spawning run, either independently or in combination with spawning stresses and injuries. Estimates of mortality based on recovery of dead tagged trout during the 1978 and 1979 runs (18% and 24%, respectively) were minimum estimates (Table 28). Most of those brown trout that were recovered dead were washed downstream against the weir gates at U.S. Hwy. 2. Many more dead fish undoubtedly were hung up on debris and not recovered, or perhaps were swept past the weir during high water periods.

There was some concern as to whether the handling and tagging of brown trout had significant effect on incidence of furunculosis and subsequent mortality. In an effort to determine this, 163 brown trout were alternately tagged or marked with a partial clip of the right pectoral fin. Identical numbers of tagged and clipped brown trout (14 each or 17%) were later recovered dead, indicating that tagging itself was not detrimental.

This is not to imply that stresses due to trapping and handling of brown trout could not increase susceptibility to furunculosis; however, we believe that handling had little or no significant impact on the brown trout population. We also know that large numbers of brown trout have died during years when no studies were being conducted on the Brule River. For example, in 1960 DNR personnel collected 71 dead brown trout on the upper Brule between late October and freeze-up (Niemuth 1967). Many brown trout that had never been handled or tagged were recovered dead during study years. Large numbers of trout undoubtedly passed upstream during periods when high water forced the weir out of operation; and after these periods, many of these untagged fish were recovered dead. Of 2,148 brown trout collected dead from 1961 through 1964, only 27% had been handled and tagged previously (Niemuth 1967).

Spawning stress and injuries were likely causes of most mortalities among rainbow trout during spring (Table 29). Mortality of rainbow trout was higher in 1980 than in 1979, concurrent with the high injury rate during 1980 (Table 27). Percentages of tagged rainbows recovered dead (0.3% and 4.1% in 1979 and 1980, respectively) were considerably lower than those for brown trout on their spawning run, and perhaps give some estimate of what the magnitude of natural mortality on the spawning run might be for brown trout if not for furunculosis.

Fishing Mortality

Many investigators make estimates of angler exploitation by comparing estimates of total harvest, based on creel survey data, with estimated total population. Because of difficulties and systematic errors involved with making mark-recapture estimates of migratory fish populations, we made no attempt at estimating population numbers for brown and rainbow trout.

TABLE 28. Numbers of brown trout recovered dead at the Hwy. 2 weir and from other sources.

Recovery Source and Category	Tagging Season Fall 1978	Fall 1979
Hwy. 2 weir:		
Tagged (during same season)	101*	270
Tag lost	4	17
Untagged	75	81
Other sources (angler tag returns, dead fish counts, etc.)		
Tagged (during same season)	23	44
Untagged	2	0
Total tagged and recovered dead**	128*	331
Total fish tagged during season	698[1]	1,354
% of tagged fish recovered dead	18	24

*Includes 14 brown trout that were fin clipped rather than tagged.
**Includes those having lost tags.
[1] Includes 82 brown trout that were fin clipped rather than tagged.

TABLE 29. Numbers of rainbow trout recovered dead at the Hwy. 2 weir and from other sources.

Recovery Source and Category	Tagging Season Spring 1978	Spring 1979
Hwy. 2 weir:		
Tagged (during same season)	4	54
Untagged	19	58
Other Sources (angler tag returns, etc.)		
Tagged	2	5
Untagged	0	0
Total tagged and recovered dead	6	59
Total fish tagged during season	1,983	1,452
% of tagged fish recovered dead	0.3	4.1

The only basis for estimating rates of angler exploitation, therefore, was by comparing numbers of tags returned by anglers over a given time period with numbers of fish originally tagged. Any estimate of fishing mortality derived in this manner should be considered a minimum, as it does not take into account that percentage of fish that lost their tags and were subsequently harvested, or those tags that were not returned by anglers who caught them, neither of which can be easily estimated.

Rawstron (1971) found a reporting rate for tagged white catfish (Ictalurus catus), largemouth bass, and bluegills caught by anglers at 61%, 54%, and 31%, respectively, at Folsom Lake, California, while California anglers have shown reporting rates from 50% to 70% for a variety of freshwater fishes with 60% as a general rule. Matlock (1981) found a reporting rate of only 28% for fish with internal abdominal tags, but failure to report the tag was most often a result of failure to find it.

During the course of this study, three different lengths of Floy tags were used, measuring 3.0, 2.2, and 1.6 inches. Studies by DNR personnel at Bayfield indicate that tag retention time increases as tag length decreases. Lake trout tagged with a 2.5-inch Floy tag showed a 35% tag loss after 12 months, while those tagged with a 1.5-inch tag only lost 3% after one year. Much of the tag loss with the longer tags was apparently due to an increased amount of spiraling movement as the fish swims, causing enlargement of the tag hole in the fish. Tag loss may be higher in brown and rainbow trout because of the amount of time spent in river currents.

The majority of returned tags were from fish that were caught during the same season they were tagged. Tag losses, therefore, may have had a minimal effect on calculated exploitation rates, unless there was an initially high loss soon after tagging that leveled off afterward. The largest bias involved may be a result of anglers not returning tags from fish they have caught.

Minimum annual exploitation rates were estimated from percentages of fish tagged during a given period which were caught during that same tagging season or the following one, and whose tags were returned by anglers. Only fish tagged during the season in which they spawned were used; i.e., brown trout tagged during fall and rainbow trout tagged during spring.

Of 1,970 brown trout tagged during fall 1978 and 1979, 38 were caught and returned during that same fall or the following spring, giving a minimum annual exploitation rate of only 1.9%. Of 3,435 rainbow trout tagged during spring 1979 and 1980, 206 were caught and returned during the same spring or the following fall, for a minimum annual exploitation rate of 6.0%.

Although these annual exploitation rates are absolute minimums and may be of limited value in themselves, they do indicate that the rainbow trout exploitation rate is approximately three times that of brown trout.

Little published information is available on exploitation rates in other Great Lakes migratory trout populations. Kwain (1981) estimated exploitation rates on adult rainbow trout in Stokely Creek, eastern Lake Superior, ranging from 15% to 21% over a 5-year period, with an average of 19%. These estimates were based both on recovery of tags through a creel census and by angler return of tags, within the year of tagging. B. Swanson (DNR-Bayfield, pers. comm.) estimated annual fishing mortality of adult rainbow trout in Pikes Creek, Wisconsin, a Lake Superior tributary, based on a creel census estimate of total harvest compared with a mark-recapture population estimate. Annual exploitation in the stream ranged from 11% to 37.7% from 1977 through 1981, averaging 21.6%. An additional 4% were harvested from Lake Superior. Estimates of annual exploitation in the stream were nearly the same for each sex from 1977 through 1980, averaging 17.6% for females and 17.0% for males.

More liberal estimates of fishing mortality may be made by entering various values for percent tag retention one year after tagging, and for estimated percentage of tags that were reported by anglers having caught tagged fish. The annual exploitation rate (u) can be estimated by:

$$u = \frac{R}{MTX} \qquad (11)$$

where:
- R = number of tags returned by anglers within one year of tagging
- M = number of fish tagged
- T = percent tag retention after one year (expressed as a decimal fraction)
- X = estimated percentage of tags reported by anglers having caught tagged fish (expressed as a decimal fraction).

Estimated values for percent tag retention would assume that all tag loss occurred immediately after tagging, rather than throughout the following year; which may actually result in a slight overestimate of exploitation rates.

Using what are likely underestimates of percent tag retention (T=0.60) and tag reporting rate (X=0.40), estimated exploitation rate using equation (11) with R=38 and M=1,970 for brown trout is still only 8%. Keeping the same values for T and X, estimated exploitation rate for rainbow trout, with R=206 and M=3,435, is 25%.

Although these adjusted estimates of exploitation rates were based partially on information from other studies as well as speculation, we feel that they are probably maximum values and provide ranges within which the true exploitation rates likely would have fallen.

Numbers of brown trout tags returned from each season after tagging (Table 30) indicate that very few were caught a year or more after being tagged. Percentages of brown trout tagged during fall 1978 and 1979 that were returned through spring 1982 (2.1% and 2.7%, respectively) are not much higher than the minimum annual exploitation rate (1.9% average for the two years). None of the 616 brown trout tagged in fall 1978 were caught and returned by anglers in fall 1979, and only two of 1,354 fish tagged during fall 1979 were caught one year later. Of 78 fish tagged in spring 1979 and 21 tagged in spring 1980 as downstream migrants, 6.4% and 9.5%, respectively have been caught and returned. Although this represents a small sample, it appears that those

TABLE 30. Brown trout tagged during each period that were caught by anglers and returned during each subsequent period, and total tag returns through spring 1982.

Tagging Period	Number Tagged	Numbers (and Percentages) Returned From Each Period								
		Fall 1978	Spring 1979	Fall 1979	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1982	Total
Fall 1978	616	7 (1.1)	2 (0.3)	0 (0.0)	2 (0.3)	1 (0.2)	0 (0.0)	0 (0.0)	1 (0.2)	13 (2.1)
Spring 1979	78	--	2 (2.6)	2 (2.6)	1 (1.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	5 (6.4)
Fall 1979	1,354	--	--	20 (1.5)	9 (0.7)	2 (0.1)	2 (0.1)	1 (0.1)	2 (0.1)	36 (2.7)
Spring 1980	21	--	--	--	2 (9.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (9.5)

brown trout that survive the spawning season are more vulnerable in the spring and make a relatively large contribution to the fishery.

Tagged rainbow trout (Table 31) made a more significant contribution to the fishery a year or more after tagging than brown trout, as their better survival through a spawning run allows them to return one or more times during the following years. Nine tags (2.7%) of 329 fish tagged during fall 1978 were returned from fall 1979 through spring 1981. A total of 7.9% and 10.1% of the tags were returned through fall 1982 from rainbow trout tagged during fall 1978 and 1979, respectively. Of 1,983 rainbow trout tagged during spring 1979, 188 tags (9.5%) were returned, of which 66 were caught after 1979. A total of 1,452 fish were tagged in spring 1980, 134 (9.2%) of which were returned through fall 1982. The total number of tag returns that can be expected from any group of tagged rainbow trout in the Brule River appears to be around 9 or 10% of those tagged.

The majority of rainbow trout that were tagged during fall at the Brule River mouth and subsequently caught, were caught the spring following tagging. The largest number of those tagged during spring at U.S. Hwy. 2 that were eventually caught, were caught later during the same season they were tagged.

Total Mortality

Total annual mortality rates were estimated using catch curves (age vs. $\log_{10}$ of numbers in catch). Numbers of fish per age group were expanded from the sample of aged trout to the entire sample of aged and non-aged upstream migrant trout from all years of the study, by the following formula:

$$N = \sum_{i=1}^{k} p_i \; n_i \qquad (12)$$

where N = number of fish per given age class in entire sample
p = percentage of aged fish within length group - i belonging to a given age class (expressed as a decimal fraction)
n = total number of fish within length group - i in entire sample
k = number of length groups

The catch curve for brown trout (Fig. 15) indicates that most, if not all, brown trout would have made their first spawning run by age IV (fifth summer of life), if not earlier. Few, if any, age V or older brown trout would be maiden spawners.

The concavity of the right limb of the curve may indicate that total annual mortality decreased with age. According to Ricker (1975), this concavity results either from a recent increase in rate of exploitation of the stock as a whole, or from a decrease in rate of natural mortality with age. The latter alternative seems most feasible in this instance. The shape of this right

TABLE 31. Rainbow trout tagged during each period that were caught by anglers and returned during each subsequent period, and total tag returns through fall 1982.

Tagging Period	Number Tagged	Numbers (and Percentages) Returned From Each Period									
		Fall 1978	Spring 1979	Fall 1979	Spring 1980	Fall 1980	Spring 1981	Fall 1981	Spring 1982	Fall 1982	Total
Fall 1978	329	4	13	3	3	2	1	0	0	0	26
		(1.2)	(4.0)	(0.9)	(0.9)	(0.6)	(0.3)	(0.0)	(0.0)	(0.0)	(7.9)
Spring 1979	1,983	--	78	44	38	10	10	4	3	1	188
		--	(3.9)	(2.2)	(1.9)	(0.5)	(0.5)	(0.2)	(0.2)	(0.1)	(9.5)
Fall 1979	395	--	--	10	23	2	0	3	2	0	40
		--	--	(2.5)	(5.8)	(0.5)	(0.0)	(0.7)	(0.5)	(0.0)	(10.1)
Spring 1980	1,452	--	--	--	47	38	17	21	10	1	134
		--	--	--	(3.2)	(2.6)	(1.2)	(1.4)	(0.7)	(0.1)	(9.2)

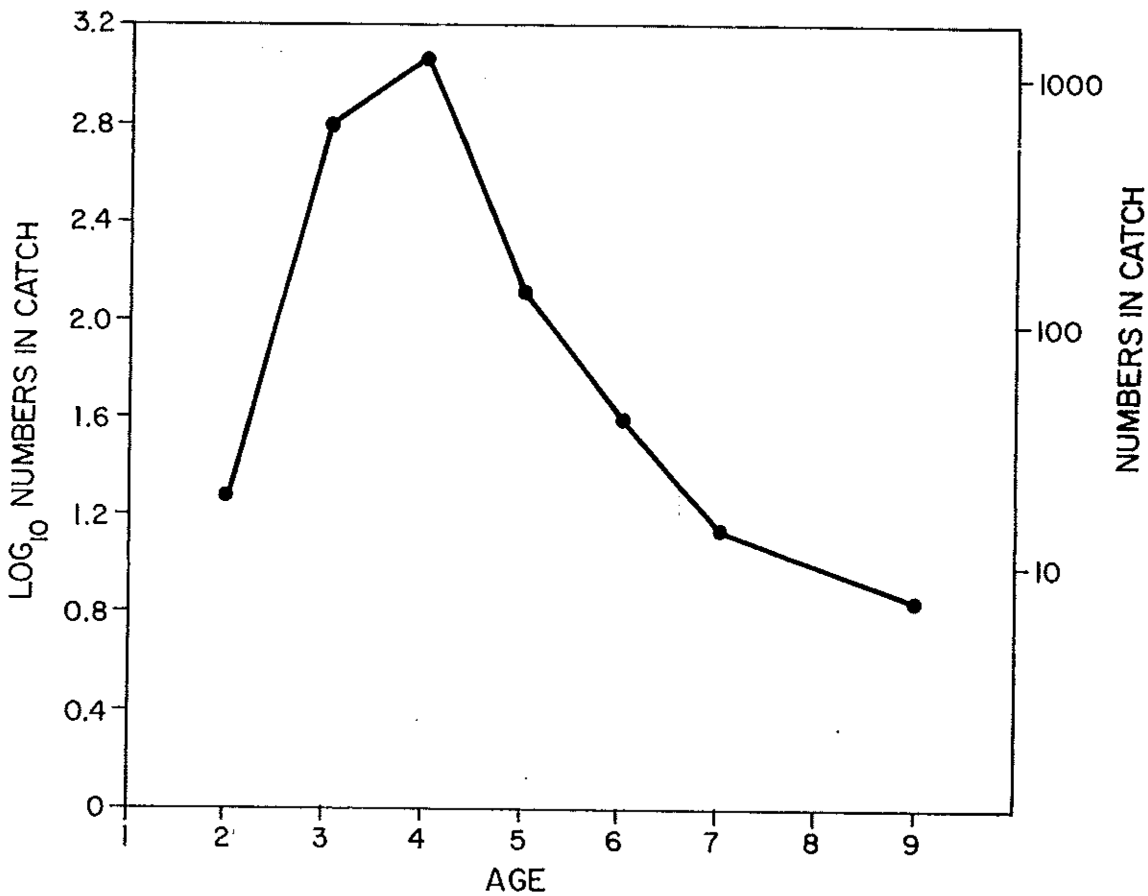


FIGURE 15. Catch curve for migratory brown trout captured in the Brule River during fall 1978 and 1979. (Numbers are expanded from the sample of aged fish to the entire sample of upstream migrants.)

limb cannot be explained as an irregularity due to variation in recruitment between year classes, as samples were combined from both years.

Total annual mortality (A) between ages IV and V was 0.89. This high mortality rate in spite of evidence of a very low rate of fishing mortality for brown trout, was likely due in large part to high natural mortality from furunculosis. We were unable to estimate total mortality rates for age II and III fish because of incomplete representation in the spawning run. If, however, we can assume that those age II and III brown trout that make a spawning run were at least as vulnerable to the various causes of mortality as age IV fish, it follows that the great majority of age IV fish, which comprise 58% of the run, were maiden spawners. Apparently then, very few brown trout survive their maiden spawning run and the year that follows, due to the collective effects of disease, spawning stress, injuries, and harvest; and at most 11% return to the Brule River a second time.

Total mortality for brown trout age V and older was considerably less than that for age IV fish. Between ages V and VI, A = 0.67; while A = 0.66 from ages VI to VII. Davis (1956) points out that individuals of the same species vary greatly in susceptibility to furunculosis, some readily contracting the disease while others resist infection entirely; and that this difference in susceptibility is probably a matter of heredity. It is possible that many of the brown trout that survive their maiden spawning run are individuals who have an inherently low susceptibility to furunculosis, and thus exhibit greater survival on subsequent spawning runs as well. Also, it is possible that some individuals acquire an immunity to the disease through repeated exposure to it.

Annual mortality rate between ages VII and IX (average A = 0.29) was unusually low; however, the number of 9-year-old fish in the catch was based on a small sample size of 9-year-olds actually aged, and can probably be disregarded as an outlier.

Rainbow trout exhibited a catch curve with broad, flattened dome, and a straight right limb indicating very constant annual mortality from year to year (Fig. 16). This curve was based on combined samples from all years of the study; however, a curve based only on aged fish captured in 1979 was nearly identical in shape, indicating stable recruitment from one year class to the next.

Ricker (1975) explains that when vulnerability to capture depends on maturity (as in the case of migratory trout populations), differences in age at maturity tend to broaden the left limb and flatten the dome of the catch curve, when sexes are combined. Age V rainbow trout, although comprising the peak of the catch curve, may have been incompletely represented in the spawning run; which would explain the seemingly low annual mortality (A = 0.24) between ages V and VI. Age at sexual maturity can vary considerably in rainbow trout, from as early as 1 year by males to as late as 6 years by females (Scott and Crossman 1973).

Average annual mortality rate for rainbow trout was calculated from the least-squares regression of age vs. $\log_{10}$ of frequency (numbers in catch) using ages VI through X only. The calculated mortality rate was 0.68; considerably less than that of most of brown trout spawners, and comparable to that of older, repeat-spawning brown trout. The greater survivorship (32%) of rainbow trout after their initial spawning run, along with apparently more variability in age at recruitment to the spawning population, resulted in an average size larger than that of brown trout and allows for more trophy size fish available to the angler.

Fishing mortality appears to have comprised a relatively small portion of the total annual mortality for rainbow trout and brown trout. Neither species at the time of study showed any indication of overharvest. Brown trout could likely be utilized to a greater extent with no adverse effect on the population, since so few survive their initial spawning run.

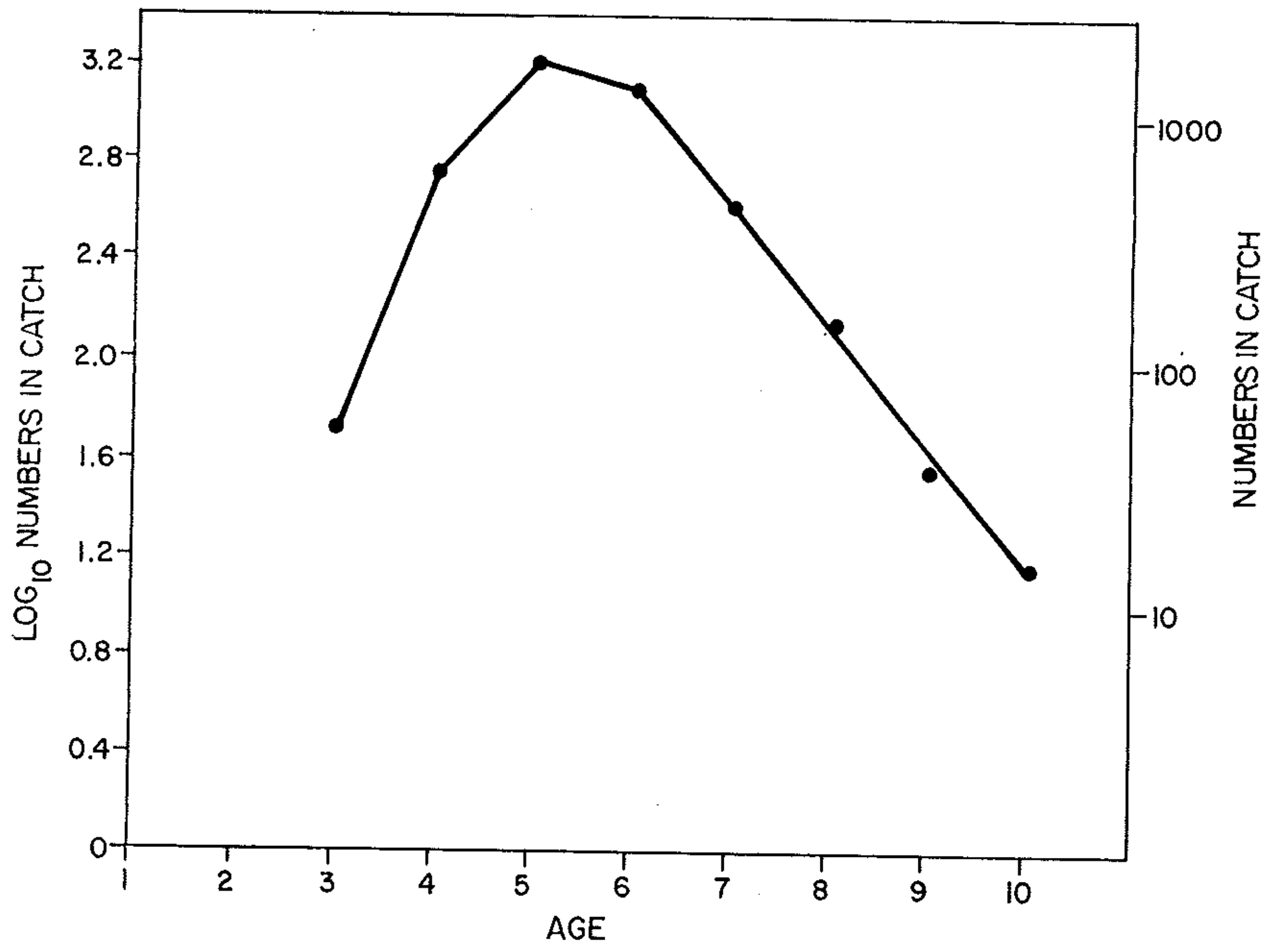


FIGURE 16. Catch curve for migratory rainbow trout captured in the Brule River, fall 1978 through spring 1980. (Numbers are expanded from the sample of aged fish to the entire sample of upstream migrants.)

LOCATIONS OF ANGLER-CAUGHT TAGGED TROUT

Catch Within Brule River

A majority (56%) of brown trout tag returns were caught above U.S. Hwy. 2, and of these most were caught above Co. Hwy. B in the Big Lake - Lucius Lake area during August and September (Fig. 17). The remainder of the brown trout tag returns were distributed fairly uniformly throughout the lower river; most of these fish were caught during spring. Many brown trout seem to follow the edge of the receding ice downstream during spring, a habit well known by fishermen. In years when the river was completely ice-free several days before the opening of the early trout season, the resulting angler catch of migratory brown trout during spring was generally poor (Niemuth 1967).

Most (92%) of the rainbow trout tag returns were caught downstream from U.S. Hwy. 2, mainly because the trout season above this boundary is closed during most of the time rainbows are in the river. Sixteen percent of these were taken in the stretch from the mouth to State Hwy. 13, 37% from State Hwy. 13 to Co. Hwy. FF, and 47% from Co. Hwy. FF to U.S. Hwy. 2. Relative catch at various locations on the river seemed to be a reflection, in large part, of the number of access points along those stretches or the close proximity of main road crossings. Four of the most popular fishing areas, based on tag returns, are the Copper Range Campground (Co-op Park) area, Co. Hwy. FF crossing, Skid Mays (Mays Ledges), and State Hwy. 13 crossing. Skid Mays is very popular, as the river here rushes over a series of ledges, between which the trout apparently congregate in large numbers and rest before continuing upstream. The relatively low numbers of rainbow trout caught below State Hwy. 13 may be due in part to the fact that this stretch was often partially ice covered during the first few days of the early trout season. Also, the bulk of the rainbow trout caught very early in the season were fish that would have been in the river since the previous fall, and many would have likely moved farther upstream by the time of the season opener.

Dispersal of Trout in Lake Superior

The increase in popularity of sport trolling for trout and salmon on Lake Superior in recent years has given the Brule River additional importance as a producer of trout for the lake fishery. Although no estimate could be made as to the actual contribution by Brule River trout to the total number of brown and rainbow trout harvested, we can tell through the geographical distribution of tag returns over what portion of Lake Superior these Brule River trout contributed to the fishery.

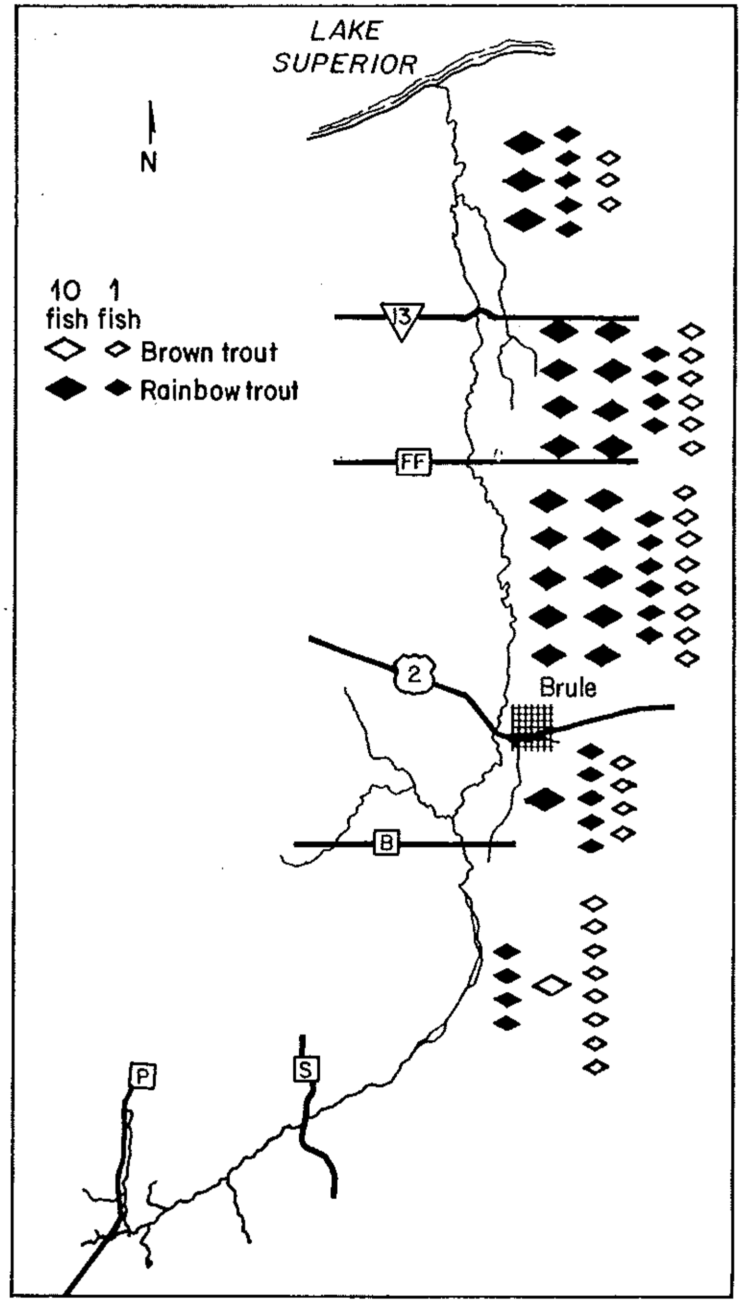


FIGURE 17. Numbers of tagged brown and rainbow trout caught in various portions of the Brule River separated by the major highway crossings from fall 1978 through fall 1980.

Most brown trout travel in an easterly direction after leaving the Brule River (Fig. 18). Although the sample of tagged brown trout caught in Lake Superior was small, only 1 of the 10 tag returns was caught west of the river mouth, having been taken off Superior Entry. Six tagged brown trout were caught in the area from the Iron River mouth east to Squaw Bay, all within approximately 30 miles of the Brule River mouth. The three most distant tag returns were caught in or near Chequamegon Bay, a distance of 55 miles or more from the Brule River mouth. Niemuth (1967) received tags from brown trout caught as far away as the Bad River mouth east of Ashland, Wisconsin, a distance of 70 miles. Niemuth speculated that brown trout leaving the Brule River follow the strong surface currents of Lake Superior, which flow eastward along the south shore.

Rainbow trout tend to stray to a much greater extent than brown trout, both in distance and direction from the Brule River (Fig. 18). Tagged rainbow trout were caught at various locations along the north shore (Minnesota) as far as the Ontario border, a distance of approximately 140 miles from the Brule River mouth, and as far east along the south shore as Keweenaw Bay, Michigan, a distance of at least 170 miles. These are direct line measurements, so actual distances these fish traveled may have been much greater. Thirty-seven tags were returned from rainbow trout caught in Lake Superior or its other tributaries, 17 (46%) of which were caught in Minnesota waters, 13 (35%) were caught in Wisconsin waters, 6 (16%) were taken in Michigan waters, and 1 (3%) was taken in Wisconsin-Michigan Boundary waters. Niemuth (1970) received only 7 tag returns from rainbow trout taken from waters other than the Brule River. The farthest distance at which a fish was caught was the Traverse River, Keweenaw County, Michigan, a distance similar to that of the Keweenaw Bay fish mentioned above.

No tagged brown or rainbow trout were caught in the area between the Brule River and Superior, Wisconsin. This is surprising since sport trolling is popular in this area. More surprising is that only 1 tag return came from the area of the Apostle Islands and Chequamegon Bay, in spite of considerable sport fishing pressure in these areas.

The distance that trout will stray and still eventually return to the Brule River is not known. Some of these trout may have originally been strays from other areas when they entered the Brule River. Some may have been stocked fish, either from plants in the Brule River or elsewhere, which lacked a desire to home to a natal stream.

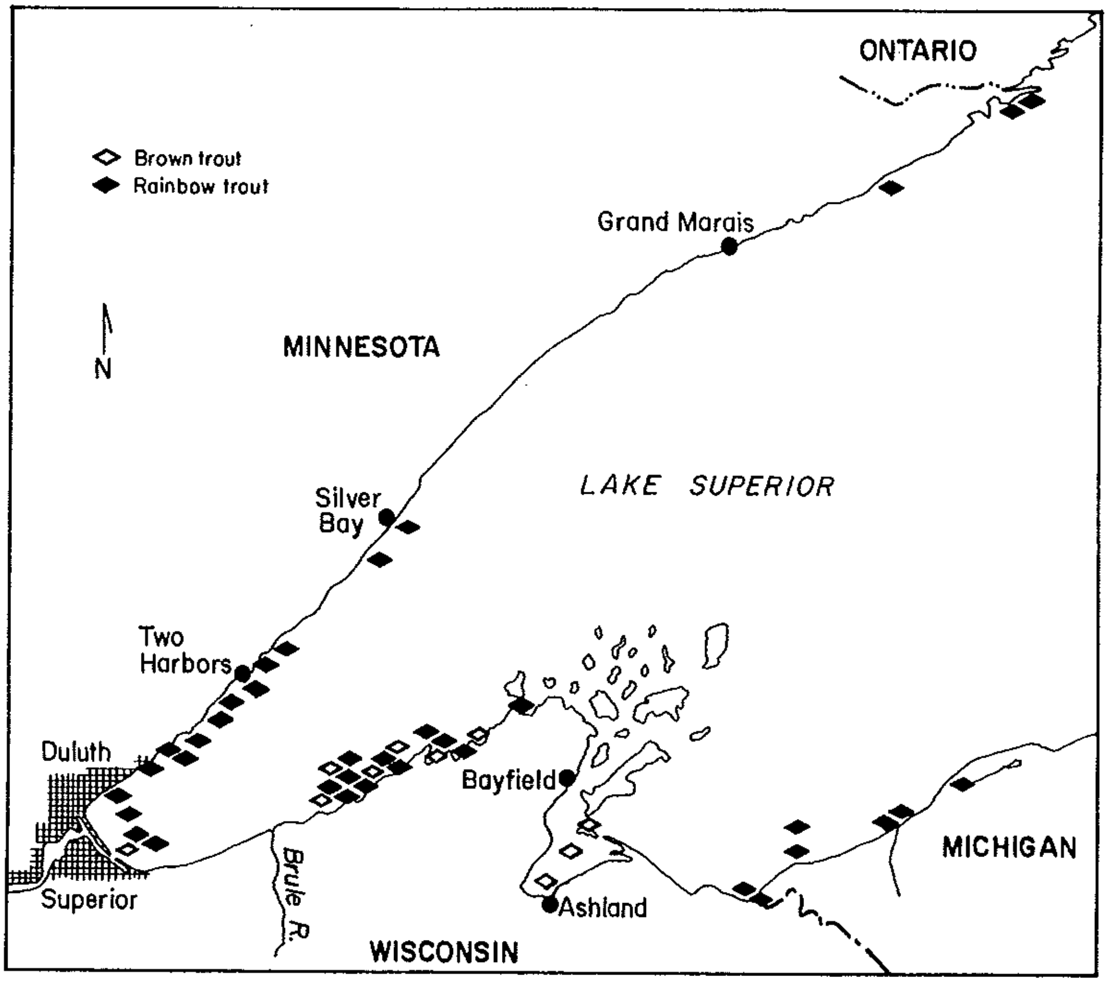


FIGURE 18. Reported locations of tagged Brule River brown and rainbow trout caught in Lake Superior and tributaries other than the Brule River from spring 1979 through fall 1983. Two additional rainbow trout were caught in Keweenaw Bay, Mich.--a minimum distance of 170 miles from the Brule River mouth.

TROUT SPAWNING

Areas and General Conditions

Little effort was made during the present study to document the times and conditions during which spawning occurred. Scattered observations indicated little or no change from observations by previous investigators.

Niemuth (1967) reported that spawning activity by Brule River brown trout begins around October 8 and peaks between mid-October and mid- November. Brown trout spawn in water between 6 and 48 inches in depth, with water temperatures ranging from the mid-50's (F) in early October to mid-30's (F) by early December.

Niemuth identified major brown trout spawning areas from the area of the Ranger Station as far upstream as May's Rips, with a limited amount of spawning between U.S. Hwy. 2 and Co-op Park. The area from just below Co. Hwy. B upstream to Spring Lake probably had the heaviest concentration of spawning use of any given stretch of river. Other major spawning areas included the rapids between Cedar Island and Big Lake, Wildcat Rapids, and the area downstream from the mouth of Nebagamon Creek. Migratory brown trout have also been documented spawning in the Little Brule River immediately below the Brule Trout Hatchery.

The only additional potential spawning area discovered during the present study was in Rocky Run above Co. Hwy. H, where several large redds were found on November 16, 1978. It was uncertain, however, if these redds were constructed by brown trout or salmon.

Brown trout spawning in some smaller tributaries is probably limited by low water levels during fall, while rainbow trout find access and spawning conditions much more suitable in these same streams during spring. This was evidenced by Casey Creek which has very little flow during late summer (Table 9). Brown trout were almost nonexistent while young-of-the-year rainbow trout were numerous.

Canoe trip observations on the upper Brule River during steelhead spawning seasons from 1977 through 1980 indicated, as Niemuth (1970) found, that rainbow trout utilize the identical spawning areas in spring that brown trout use during fall. It appears that virtually every available area of suitable gravel in this portion of the river is used to some degree by spawning rainbow trout. Many redds are in close proximity to each other, particularly in shallower, faster water; while in some deeper areas, very large redds, described by Niemuth as "community redds", can be seen. As many as 293 redds and 738 adult rainbow trout were counted between May's Rips and the Ranger Station (April 9 and 10, 1979).

Other observations show that many additional areas were used by spawning rainbow trout. Spawning activity has been reported in the area of Co-op Park, and also from areas between Co. Hwy. FF and State Hwy. 13. Rainbow trout spawning and/or reproduction was documented as far upstream as the East Fork, West Fork, and in Wilson Creek (Table 7). One tagged rainbow trout was observed in Wilson Creek over a mile upstream from its mouth on May 4, 1979. The Nebagamon - Blueberry Creek system also was a very important spawning and nursery area for rainbow trout.

Niemuth (1970) reported that Brule River rainbow trout normally began spawning activity in late March or early April, and completed most spawning by mid-May. Spawning peaked during April with water temperatures ranging from the low 40's (F) to mid-50's (F). Dates of spawning varied considerably with weather conditions. For example, rainbow trout spawning activity was observed as early as March 8, 1981, during an unusually mild winter.

Rainbow trout spawning began earlier in the Brule River than in other Lake Superior tributaries, summarized by Biette et al. (1981), in which spawning began between the 4th week of April and the 3rd week of May.

Biette et al. (1981) reported fall and winter spawning activity by rainbow trout in several Great Lakes tributaries, occurring immediately after the fall migration. No fall-winter rainbow trout spawning has ever been documented in the Brule River, despite the large fall run.

Repeat Spawning

Based on the previously estimated annual mortality of 89%, 11% of all brown trout spawners tagged in 1978 should have survived to return to the Brule River in 1979. We accounted for 38% of this theoretical 11% (4.2% of total tagged in 1978) actually returning in 1979, based on angler tag returns, recaptures, and tagged fish recovered dead (Table 32). Although it is possible that some brown trout do not return to spawn every year, we believe that most probably do; and that many repeat spawners either lost tags or simply avoided recapture in 1979.

TABLE 32. Numbers and percentages of brown and rainbow trout tagged during the fall 1978 - spring 1979 spawning run that are known to have returned during the fall 1979 - spring 1980 run, based on angler tag returns, recaptures, and fish recovered dead.

Species	Number Tagged Fall 1978 - Spring 1979	Fish Returning Fall 1979 - Spring 1980 Angler Returns	Recovered Dead	Recaptures	Total	Percent Return
Brown trout	694	5	2	22	29	4.2
Rainbow trout	2,312	88	0	96	184	8.0

Repeat spawning rainbow trout can similarly be only partially accounted for. Only one-fourth of a theoretical 32% returning during the second year of the study were recaptured or caught by anglers (Table 32).

CREEL SURVEY

Problems and Biases

Several inherent biases were encountered in the creel survey due to the nature of the Brule River and its fishery, the distribution of public accesses, and use of the river by the various user groups. Many of these biases tend to affect census data from the upper river (upstream from U.S. Hwy. 2) more so than the lower river, and tend to affect data for brown trout more than for rainbow trout.

A large percentage of river frontage on the upper river, particularly between Co. Hwy. B and Stone's Bridge, is under private ownership and public access is limited to a few locations. Consequently, most of the angling public is limited to fishing by canoe on much of this stretch of river. A significant amount of fishing, however, is no doubt done by anglers staying at the many seasonal and permanent dwellings along this portion of the Brule River. These anglers and their catches are never seen by a creel clerk stationed at the few public access points, resulting in a relatively small sample of anglers interviewed. This small sampling of anglers on the upper river also reduces the size and validity of the sample of brown trout, which makes up the bulk of the fishery as compared to rainbow trout on the upper river.

The fact that night fishing on the Brule River is a popular activity also reduces validity of data, since the creel survey was conducted during daylight hours. Night fishing is especially popular for brown trout on the upper river. Many of the large migratory brown trout are taken at night in the Big Lake - Lucius Lake area of the Brule River. These anglers and harvested trout were missed by the creel survey. Another group probably not sampled in comparison to their impact on the fishery were anglers that targeted on migrations during specific productive fishing times that may have been missed during a random census.

Another inherent bias involves instantaneous car counts. Many cars parked at access points along the river may belong to non-anglers (e.g., canoeists, tubers, hunters, berrypickers, etc.); therefore, estimates of fishing pressure based on car counts may be overestimated in some cases, as are estimates of harvest which were derived from pressure estimates.

Data Input

The difficulties involved in obtaining creel survey information upstream from U.S. Hwy. 2 were reflected in numbers of instantaneous car counts, angler interviews, and trout actually recorded during the survey period (Table 33). Only 55 (17%) of 333 instantaneous counts and 67 (7%) of 962 angler interviews were recorded upstream from U.S. Hwy. 2. Nine (32%) of a total of only 28 brown trout recorded were caught on the upper river. This small total compares with 277 rainbow trout recorded during the survey on both river sections. Only 13 (5%) of these rainbow trout were caught on the upper river, but this may be due at least in part to a greater availability of rainbow trout to the angler on the lower river (downstream from U.S. Hwy. 2) as a result of the fishing season framework.

Fishing Pressure

Mean number of anglers per party was 1.8 overall for the entire river during the survey period (Table 34). Number per party was higher downstream from U.S. Hwy. 2 than upstream, and was higher from the season opening through June 1979 than from July 1978 through the close of the season.

The overall mean length of a fishing trip was 3.8 hours (Table 34). Shortest fishing trips took place from July 1978 through the close of the season upstream from U.S. Hwy. 2 (1.8 hours), while longest trips (5.7 hours) were from the season opening through June in 1979, also above U.S. Hwy. 2.

An estimated total of 38,800 anglers fished on 21,941 separate outings on the Brule River from July 1978 through June 1979, and spent 150,446 hours fishing (outing is defined as the combined trips by all anglers in a party). Total fishing pressure in general was substantially higher on the lower river than it was upstream from U.S. Hwy. 2; with 81% of the outings, 84% of the anglers, and 88% of the total angling hours.

Total number of anglers for the year was 33% higher than an estimated 29,075 anglers in a 1973 creel survey on the Brule River (DNR unpubl. rep., Brule). Nearly all (81%) of this increase in angler numbers took place during the summer-fall period (July 1 through close of the season) on both the upper and lower river.

Fishing pressure in total angling hours was greater downstream than upstream from U.S. Hwy. 2 during any given month (Fig. 19). Peak fishing pressure on the lower river occurs during April and October with 44,044 and 27,134 angling hours, respectively. Lowest pressure was during August with 5,234 angling hours. Peak pressure on the upper river was during June with 5,425 angling hours, while lowest pressure was during September (1,517 hours).

The percentage of Wisconsin resident to nonresident anglers fishing the Brule River was very consistent between different river sections and time periods. Overall percent resident to nonresident anglers ranged from 65-35% to 71-29% for the river as a whole. The most popular river section with nonresidents is the area immediately upstream and downstream from Co. Hwy. FF on the lower river, where nonresidents comprised 46% of all anglers during the April - June, 1979 period.

TABLE 33. Summary of creel survey input data.

Survey Period	River Section	Number Instantaneous Counts	Number of Angler Interviews	Brown Trout in Sample	Rainbow Trout In Sample
1978					
Jul - Nov	Below U.S. Hwy. 2	181	459	13	68
Jul - Sep	Above U.S. Hwy. 2	36	21	1	0
1979					
Mar - Jun	Below U.S. Hwy. 2	97	436	6	196
May - Jun	Above U.S. Hwy. 2	19	46	8	13
Totals		333	962	28	277

TABLE 34. Fishing pressure statistics on the Brule River.

	Downstream from U.S. Hwy. 2		Upstream from U.S. Hwy. 2			
	1978[1]	1979[2]	1978[3]	1979[4]	Total	Overall Mean
Party size (mean no. per party)	1.7	2.0	1.4	1.6	-	1.8
Trip length (mean no. hours)	3.3	5.0	1.8	5.7	-	3.8
Outings (total no.)	10,371	7,421	3,035	1,114	21,941	-
Anglers (total no.)	18,213	14,570	4,237	1,780	38,800	-
Angling hours (total no.)	60,104	72,743	7,415	10,184	150,446	-

[1]July through November.
[2]April through June.
[3]July through September.
[4]May through June.

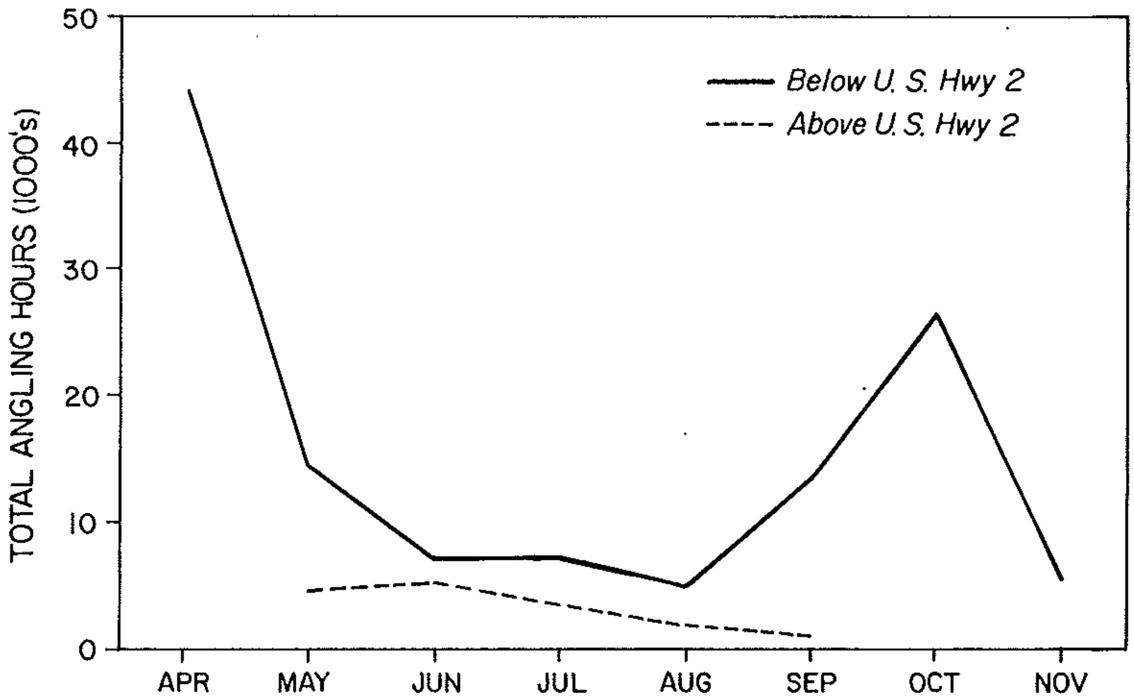


FIGURE 19. Total angling hours by month on the Brule River upstream and downstream from U.S. Hwy. 2.

Projected Harvest and Harvest Rates

Highest monthly harvest and harvest rates (fish per hour) of brown trout (all sizes) downstream from U.S. Hwy. 2 occurred during July when 412 brown trout were taken (0.06 trout/hour) (Table 35). Above U.S. Hwy. 2, the greatest brown trout harvest occurred during June (483 fish, 0.09 trout/hour). The highest harvest rate on the upper river occurred during September (0.14 brown trout/hour); however, this is based on a small sample of brown trout actually recorded.

Total harvest of brown trout of all sizes for the entire regular trout fishing season was estimated at 920 and 762 fish respectively downstream and upstream from U.S. Hwy. 2. Overall harvest rates were 0.02 and 0.04 trout/hour, respectively, for the lower and upper river sections.

Few brown trout were recorded by the creel survey during either the early or late special trout seasons on the lower Brule River. Spawned out brown trout often are caught during the early season as they seem to follow the edge of the receding ice downstream. During most years prior to year-round fishing on the lower river, including the year of the creel survey, the river was nearly ice-free by the opening of the early trout season.

TABLE 35. Harvest statistics for brown trout creeled on the Brule River.

Survey Period	Downstream From U.S. Hwy. 2			Upstream From U.S. Hwy. 2		
	Total Harvest	Harvest Rate	Hours Per Fish	Total Harvest	Harvest Rate	Hours Per Fish
1978						
July	412	0.055	18.2	0	0.000	--
August	73	0.014	71.4	0	0.000	--
September	141	0.010	100.0	217	0.143	7.0
October	0	0.000	--	--	--	--
November	0	0.000	--	--	--	--
1979						
March 31	16	0.002	500.0	--	--	--
April	0	0.000	--	--	--	--
May	132	0.009	11.1	62	0.013	76.9
June	162	0.022	45.5	483	0.089	11.2
Early season (Mar - Apr)	16	0.001	--	--	--	--
Regular season (May - Sep)	920	0.019	52.6	762	0.043	23.3
Late season (Oct - Nov)	0	0.000	--	--	--	--

Estimated harvest and harvest rates for brown trout of all sizes were compared with those fish 13 inches or larger, which roughly approximates the minimum size of a returning lake-run brown trout (Table 36). Greatest harvest of brown trout of both categories for any time period or river section occurred on the lower river from July through November when 626 total brown trout were taken, 235 of them 13 inches or larger. Highest harvest rates for both categories, however, occurred on the upper river; from May through June for brown trout of all sizes, and July through September for those 13 inches or larger.

In general, more brown trout (all sizes) were caught in the lower Brule River during the year, despite the more seasonal nature of the trout fishery on that section. Anglers on the upper river, however, experienced better fishing in terms of numbers of brown trout harvested per hour.

Greatest numbers of rainbow trout of all sizes were harvested during June, April, May, and October (2,815, 2,114, 1,739, and 1,655 fish, respectively) on the Brule River below U.S. Hwy. 2 (Table 37). Numbers harvested during these four months were substantially higher than totals during all remaining months. Highest harvest rate on the lower river was during June also (0.38 fish/hour) while the lowest harvest rate occurred in November (0.02 fish/hour). Rainbow trout were recorded on the upper river only in May and June; again June had the highest harvest (483 rainbow trout) and harvest rate (0.09 fish/hour).

Rainbow trout total harvest (all sizes) (5,906) and overall harvest rate (0.12 fish/hour) during the regular trout season were substantially higher than during either the early or late special seasons on the lower river. More total rainbow trout were caught during the early season (3,325) than during the late season (1,784), and overall harvest rate was slightly higher in the early season as well (0.07 compared with 0.05).

Estimated total harvest and harvest rates for rainbow trout of all sizes were compared with those for fish 13 inches and larger, which roughly approximates the minimum size of a returning rainbow (steelhead) trout (Table 38). Downstream from U.S. Hwy. 2, 7,489 (68%) of an annual harvest total of 11,015 rainbow trout were 13 inches or larger. Overall annual harvest rates on the lower river were 0.08 fish per hour for rainbow trout of all sizes and 0.06 per hour for steelheads. Total harvest and harvest rates for the March-June period were approximately double those for the July-November period in both size categories. All 702 rainbow trout harvested upstream from U.S. Hwy. 2 were caught during the May-June period; and of these, 253 (36%) were 13 inches or greater. Harvest rates on the upper river were 0.04 trout per hour for rainbows of all sizes and 0.014 per hour for steelheads.

Approximately two-thirds of a group of 60 small (pre-smolt) rainbow trout that were recorded by the creel survey at U.S. Hwy. 2 and downstream between May 13 and June 27, 1979 were fin-clipped fish that had recently been released from the Brule Trout Rearing Station on the Little Brule River. The presence of large numbers of these hatchery trout during this period likely resulted in overestimates of numbers of small rainbow trout that would otherwise have been creeled on the lower river.

TABLE 36. Total harvest and harvest rates (fish per hour) for brown trout of all sizes and those ≥13 inches creeled on the Brule River.

Survey Period	Downstream From U.S. Hwy. 2				Upstream From U.S. Hwy. 2			
	All Sizes		≥13 inches		All Sizes		≥13 inches	
	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate
1978 July - November*	626	0.010	235	0.004	217	0.029	217	0.029
1979 March 31 - June**	310	0.004	208	0.003	545	0.054	156	0.015
Annual totals	936	0.007	443	0.003	762	0.043	373	0.021

*Trout season and creel survey period on upper river was July - September.
**Trout season and creel survey period on upper river was May - June.

TABLE 37. Harvest statistics for rainbow trout creeled on the Brule River.

Survey Period	Downstream From U.S. Hwy. 2			Upstream from U.S. Hwy. 2		
	Total Harvest	Harvest Rate	Hours Per Fish	Total Harvest	Harvest Rate	Hours Per Fish
1978						
July	726	0.097	10.3	0	0.000	--
August	146	0.028	35.7	0	0.000	--
September	480	0.034	29.4	0	0.000	--
October	1,655	0.061	16.4	--	--	--
November	129	0.021	47.6	--	--	--
1979						
March 31	1,211	0.180	5.6	--	--	--
April	2,114	0.048	20.8	--	--	--
May	1,739	0.119	8.4	219	0.046	21.7
June	2,815	0.382	2.6	483	0.089	11.2
Early season (Mar - Apr)	3,325	0.066	15.2	--	--	--
Regular season (May - Sep)	5,906	0.121	8.3	601	0.034	29.4
Late season (Oct - Nov)	1,784	0.054	18.5	--	--	--

TABLE 38. Total harvest and harvest rates (fish per hour) for brown trout of all sizes and those ≥13 inches (steelheads) creeled on the Brule River.

Survey Period	Downstream From U.S. Hwy. 2				Upstream From U.S. Hwy. 2			
	All Sizes		≥13 inches		All Sizes		≥13 inches	
	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate	Total Harvest	Harvest Rate
1978 July - November*	3,136	0.052	2,289	0.038	0	0.000	0	0.000
1979 March 31 - June**	7,879	0.108	5,200	0.071	702	0.069	253	0.025
Annual Totals	11,015	0.083	7,489	0.056	702	0.040	253	0.014

*Trout season and creel survey period on upper river was July - September.
**Trout season and creel survey period on upper river was May - June.

In comparison with the 1973 creel survey, numbers of migratory adult brown trout and steelheads harvested annually have increased, while harvest of smaller brown and rainbow trout has decreased. Annual harvest of migratory brown trout has increased from 485 to 816 (68%) since 1973, while harvest of smaller brown trout decreased from 1,007 to 882 (12%). Annual harvest of migratory rainbow trout increased from 4,779 to 7,742 (62%) since 1973, while harvest of small rainbow trout decreased from 4,160 to 3,975 (4%). These figures are based on the assumption that 13 inches is an approximate division between returning migratory trout and pre-smolt or stream-resident members of a species in order to make data from the present study comparable to the 1973 creel survey, which separated migratory from non-migratory trout. In actuality, however, the magnitude of increases and decreases may be less extreme, particularly in brown trout, as many stream resident brown trout reach lengths greater than 13 inches.

Rainbow trout 13 inches or larger (steelheads) were caught and kept by 135 (14%) of 962 anglers interviewed during the creel survey (any time of year, any river section). Of those who harvested one or more steelheads, 88% had kept either 1 or 2 fish, 5% kept 3 fish, 5% kept 4 fish, and only 1.5% had caught and kept a limit of 5 fish. Those anglers who kept 3 or more steelheads accounted for 29% of all steelheads recorded by the creel survey, while those who kept 4 or more accounted for 18% of all steelheads harvested. Many anglers have expressed concern over possible overharvest of steelheads and have suggested reduced daily creel limits. If the daily limit were reduced to 2 rainbow trout, and assuming that those anglers now harvesting 3 or more steelheads per day would catch a limit of 2 fish, total harvest of steelheads would be reduced by a maximum of 13%. Similarly, lowering the daily limit to 3 fish would reduce total harvest by a maximum of 10%. It must be remembered that these reductions are maximum estimates, as some anglers who would normally have kept more trout will simply return more often to fish. Some percentage of this reduction may be distributed to other anglers, but this percentage may be very small since anglers who presently harvest very few fish either do so because they are less skillful than others or because they voluntarily choose to practice catch and release. A reduced daily creel limit to 2 or 3 fish would, therefore, likely result in a minimal reduction in total harvest of steelhead trout.

Highest chances of successful trout fishing (trout of any species, including brook trout) were during the spring period (March-June below U.S. Hwy. 2, May-June above U.S. Hwy. 2) (Table 39). Success was greater during this period on the upper river where 34.1% of fishermen were successful (caught at least 1 trout) in an average of 4.3 hours/fish. The next best period and river section for success was on the lower river from July through November, while the period and river section of poorest success was July through September on the upper river.

Size and Age of Harvested Trout

Sample size of brown trout lengths actually recorded by the creel survey was small (Table 40); therefore, mean lengths derived from these data may be non-representative. Some of the largest brown trout recorded (up to 25.0

TABLE 39. Percent of trout fishermen that were successful (in catching one or more trout) and mean number of hours per fish creeled.

Survey Period	Lower River % Successful	Lower River Hours Per Fish	Upper River % Successful	Upper River Hours Per Fish
1978 July - November*	12.9	18.5	4.8	31.2
1979 April - June**	25.1	10.9	34.1	4.3

*Trout season and creel survey period on upper river was July - September.
**Trout season and creel survey period on upper river was May - June.

TABLE 40. Length of brown and rainbow trout creeled on the Brule River.

Survey Period	River Section	Brown Trout Sample Size	Brown Trout Mean Length (inches)	Brown Trout Mean Range (inches)	Rainbow Trout Sample Size	Rainbow Trout Mean Length (inches)	Rainbow Trout Mean Range (inches)
1978							
July - November	Lower	8	13.0	9.7 - 20.0	62	18.8	6.0 - 29.9
July - September	Upper	1	13.5	--	0	--	--
1979							
March 31 - June	Lower	3	16.7	11.0 - 25.0	131	17.5	6.0 - 28.9
May - June	Upper	7	11.7	8.3 - 16.0	11	14.2	8.9 - 28.5

inches) were taken on the lower river as spawned out downstream migrants during spring.

Overall mean lengths of rainbow trout harvested were higher (18.8 inches) during the summer-fall period than during the spring period (17.5 inches) on the lower river. Upstream from U.S. Hwy. 2, harvested rainbow trout averaged 14.2 inches. Rainbow trout that were recorded by the creel survey ranged from legal length (6.0 inches) to 29.9 inches.

Those rainbow trout 13 inches or larger (assumed to be steelheads) that were harvested during the present study averaged 22.4 inches and 22.6 inches, respectively, during spring and fall periods. These figures compare with means of 21.4 and 21.9 inches, respectively, during spring and summer-fall periods in the 1973 creel survey. Niemuth (1970), in a voluntary creel survey on the Brule River, reported mean lengths of harvested steelheads at 21.3, 19.9, and 21.1 inches, respectively, for summer-fall periods in 1962, 1963, and 1964. Actual mean lengths of harvested rainbow trout during Niemuth's study may have been smaller yet, as some anglers may have neglected to register the smaller fish they caught.

Average size of harvested migratory rainbow trout appears to have increased somewhat since the early 1960's and also since the 1973 creel survey, but size of harvested steelheads has not paralleled the substantial increase in length of fish in the population. This was also evidenced in the age structure of harvested rainbow trout compared with age structure in the population, based on sample catch in the Hwy. 2 weir (Fig. 20). Age structure of the harvest roughly parallels age structure in the population at age V and older. Harvest of age III and IV fish, however, appears disproportionately high for the number of rainbow trout present in those age groups, and suggests greater vulnerability of younger, immature fish to angling. The disproportionate harvest of younger rainbow trout tends to reduce the average length of fish in the harvest. This harvest pattern should not reduce average length (or age) of fish in the population as long as recruitment remains adequate and total harvest does not increase substantially. Differences in age at maturity result in a "pool" of younger, immature trout in Lake Superior which are recruited to the stream fishery at different ages. This phenomenon may be acting as a buffer to protect against overharvest of younger age groups, since not all members of a year class become vulnerable to harvest in the stream at the same time, thereby allowing sufficient numbers to survive into the older age and larger size groups.

Similar comparisons could not be made between population and harvest age structure for brown trout, because of the small sample size (n=19) recorded by the creel survey. Similar catch curves for brown trout would probably also show divergence in numbers between angler catch and weir catch as age increases. This same "pool" effect would also hold true as younger brown trout in Lake Superior are recruited to the spawning run at different ages. The most important benefit of this effect to brown trout may be to protect against having all members of a year class exposed to natural mortality through furunculosis and other stresses in years when conditions for these factors are especially bad.

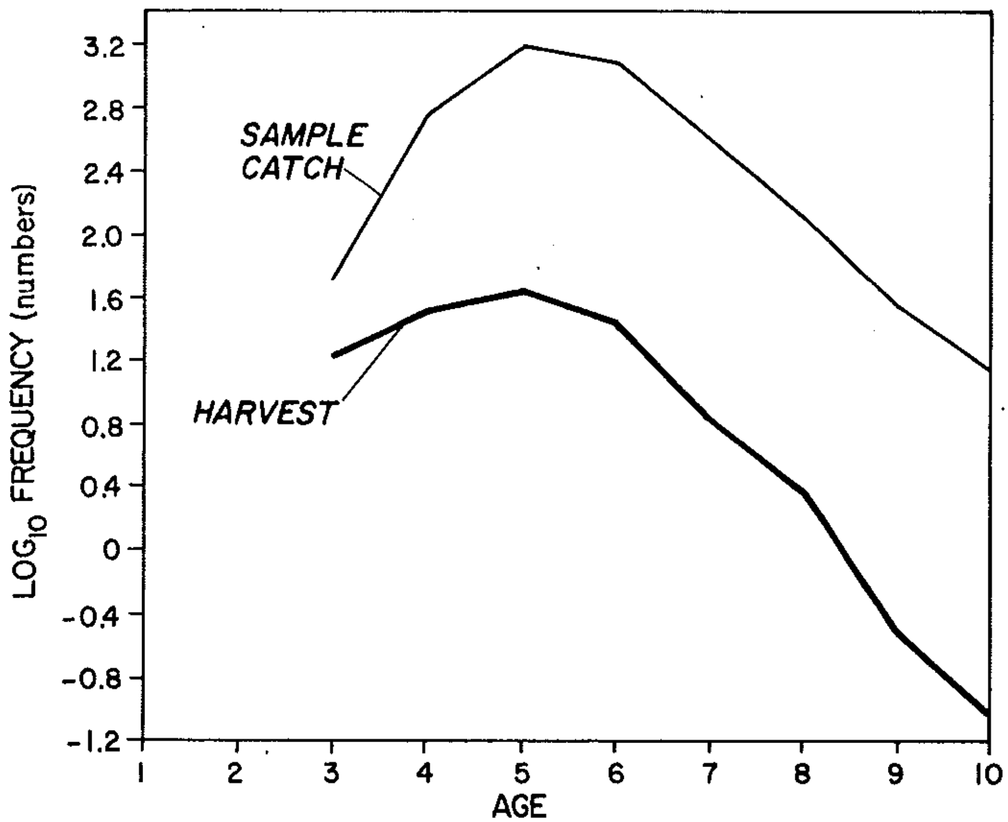


FIGURE 20. Comparison of rainbow trout catch curves based on sample catch (weir and electrofishing catch) and harvest data (from creel survey).

SALMON IN THE BRULE RIVER

Three species of Pacific salmons were found to inhabit and/or spawn in the Brule River system: coho, chinook, and pink salmon. Each of these species dies immediately after spawning.

Nine live adult coho salmon were captured between October 5 and November 12, 1978, 6 of which were captured in the Hwy. 2 weir and 3 at the Brule River mouth. One dead coho salmon was recovered at the Hwy. 2 weir on October 28. In 1979, 6 live coho salmon were captured between October 17 and November 15: 3 at the Hwy. 2 weir, 2 at the Brule River mouth, and 1 downstream from Cedar Island on the upper river. Lengths during both years ranged from 15.9 to 26.7 inches and averaged 23.1 inches.

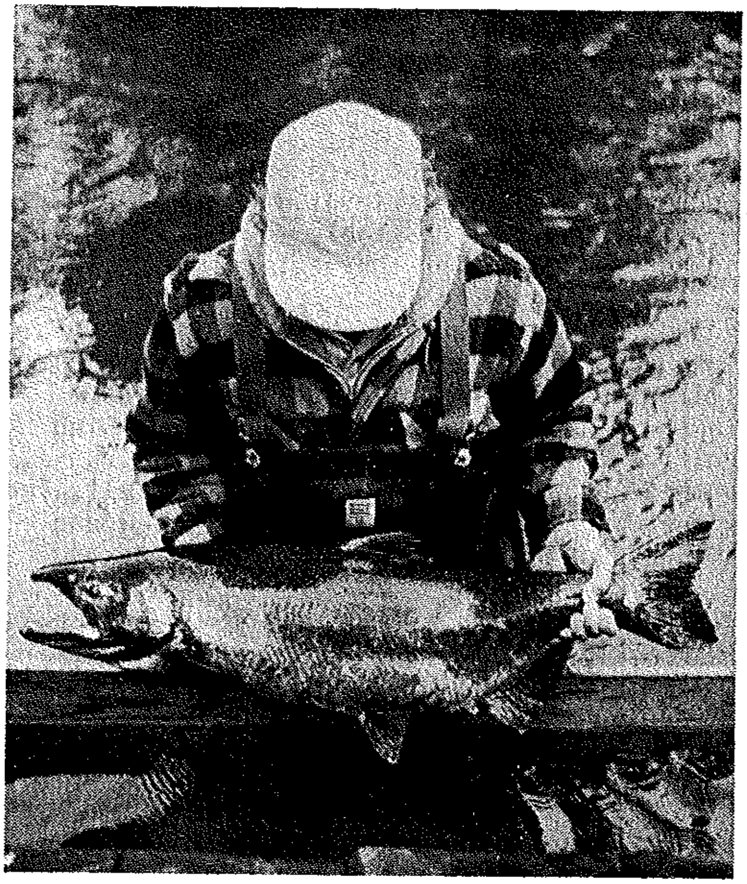
Coho salmon reproduction was apparently limited. No juvenile coho salmon were captured as part of the present study, although DNR crews from Bayfield collected 1 young-of-the-year specimen in 1973 and 4 in 1979 in the Little Brule River as part of an annual fall survey on selected streams to assess status of salmon reproduction.

Two adult chinook salmon were captured each year during 1978 and 1979. The two 1978 fish were captured at the Hwy. 2 weir on September 14 and October 20. One 1979 fish was captured on September 23 at this weir, while the other fish, already migrating upstream on June 22, was captured at the electric lamprey weir. Five adult chinooks were recovered dead during 1978. Lengths of chinook salmon for both years ranged from 25.5 to 35.1 inches and averaged 29.8 inches. The largest individual weighed 16.5 pounds.

Young-of-the-year chinook salmon were found in Blueberry Creek during August 1979, the first time natural reproduction of that species has been documented in a Wisconsin tributary to Lake Superior. The 51 individuals captured averaged 3.7 inches in length and were most numerous within the first 1,000 ft above the confluence with Nebagamon Creek. In addition, 1 individual was collected near Cedar Island on the upper Brule, and 2 were collected at the Brule River mouth in October 1979; 1 young-of-the-year chinook salmon was collected in the Little Brule River during the annual fall salmon survey that same year. Numbers of spawning adults may increase as these fish mature and return home to the Brule River to spawn.

According to Scott and Crossman (1973) there is some variation in the length of stream residency of juvenile chinook salmon. In some stocks the fry proceed almost directly to the sea, while in other stocks they are known to remain in the stream for as many as one or two years. Little is known about length of stream residency of Brule River chinook salmon, although we know they remain at least several months.

Coho and chinook salmon were never stocked in the Brule River and only chinook salmon have ever been stocked into Wisconsin waters tributary to Lake Superior (Black River, Douglas Co.). These salmon were originally strays into the Brule River from plants by neighboring states. Chinook salmon stocking in the Black River began in 1977; so these fish, because they would not have matured



Three species of Pacific salmons including chinook (above), coho, and pink salmon currently spawn in the Brule River. Coho and chinook salmon are known to be reproducing successfully. The impact of these exotics on trout populations in the Brule remains to be seen.

soon enough, could not have accounted for the natural reproduction found in the Brule River system in 1979.

The most significant run of pink (humpback) salmon to date (through the time of this study) in the Brule River was during fall 1979, according to observations from anglers. We were unable to trap upstream migrating pink salmon in the Hwy. 2 weir because these thin-bodied fish were able to slip between the rods of the weir gates. Pink salmon were observed on a spawning site immediately upstream from the weir from September 26 through October 10, 1979, and 12 individuals were captured or recovered dead during this time. These fish, most of which were males, ranged in length from 14.1 to 16.8 inches, and averaged 15.4 inches. All were in a very emaciated condition with frayed fins and discolored areas on the skin.

Pink salmon were inadvertently introduced into Lake Superior by the Province of Ontario in 1956, and have since spread throughout the upper Great Lakes. Since pink salmon have a 2-year maturation cycle, and the original stock was of the 1955 year class, pink salmon have in the past made spawning runs only on odd-numbered years. Kwain and Chappel (1978), however, reported the first known incidence of even-year spawning pink salmon in 1976 in the Steel River, Ontario, a Lake Superior tributary. Since that time, even-year spawning pink salmon have been reported from other rivers and 3-year old individuals have been verified. Even-year spawners will inevitably become common in streams that now have odd-year runs. There have been no reports of even-year spawners in the Brule River to date.

Pink salmon do not appear desirable as a sport or food fish once they have migrated some distance upstream because of their deteriorated physical condition at the time of spawning. They would be desirable to the angler if they can be caught in Lake Superior or shortly after they enter a river.

The Pacific salmons, to date, have not demonstrated any obvious adverse effects on trout populations in the Brule River, since migratory brown and rainbow trout populations were similar to those reported in past studies. Their effects, however, may remain to be seen if numbers of salmon spawning successfully were to increase significantly. Coho and especially chinook salmon have the potential to outcompete brown trout, spawning during fall, for available or preferred spawning sites, because of their larger size. Young salmon could potentially compete with juvenile trout for available food and habitat.

Pink salmon may not compete to a great extent with trout while in the river because of life history differences. There were no reports during 1979 of pink salmon upstream from U.S. Hwy. 2, so competition with brown trout on major spawning areas farther upstream may be unlikely. Also, most spawning of pink salmon apparently takes place in late September and early October, before the majority of brown trout spawning takes place. According to Scott and Crossman (1973), pink salmon as adults or young feed very little or do not feed at all while in a stream, so direct competition with trout for available food is unlikely. The fry in another Lake Superior tributary were observed to move downstream within one month after emergence (Kwain and Lawrie 1981). The greatest concern regarding pink salmon may be their possible effects on the fish community in Lake Superior.

SUMMARY AND CONCLUSIONS

Changes that have occurred relative to use and management of the Brule River, and the fish community of Lake Superior and tributaries since the early 1960's, appear to have affected migratory rainbow trout populations but not migratory brown trout in the Brule River. Control of sea lampreys has likely had the greatest impact on migratory trout populations of any of the changes that have occurred.

Numbers of migratory brown trout in the 1978 and 1979 spawning runs were very similar to numbers found during the early 1960's, despite public concern that brown trout populations were declining. Brown trout numbers may or may not have been greater at some other point between the early 1960's and 1978. Brown trout populations may be somewhat cyclic, as periods of peak abundance may bring about higher incidence of and susceptibility to furunculosis, which in turn reduces their numbers.

Size and age structure of migratory brown trout in the spawning run has changed little since the earlier study. Average length during both periods was approximately 22 inches. Age IV fish made up the largest percentage of the population during both periods, with ages III and V second and third in abundance, respectively. A few brown trout age VII and older were captured during the present study but were lacking during the earlier study.

Rainbow trout have increased dramatically both in numbers and average size since the early 1960's. The highest monthly total catch of upstream migrant rainbow trout in the Hwy. 2 weir during the present study (March 1979) was 37 times greater than the highest monthly total during the earlier study (March 1963), with a comparable amount of effort. Total catch per effort was consistently higher through all periods during the present study. Average length was approximately 25 inches during the present study, compared with 20.4 inches during the early 1960's. Dominant age classes during the earlier study were ages III, IV, and V, with ages VII and older lacking. During this study ages V and VI dominated, with fish through age X also captured.

Dominant year classes in both the rainbow and brown trout runs during the study did not correspond to years when significant numbers of these species were stocked in the Brule River, and therefore appeared to be the result of natural reproduction rather than stocking.

The increase in numbers and average size of rainbow trout may be attributable to reduction in sea lamprey numbers during the 1960's. Evidence suggests that sea lampreys selectively prey on the largest individuals in lake trout populations (Lawrie and Rahrer 1973, Pycha and King 1975), and the same may hold true for rainbow and brown trout. This selective predation on larger individuals would effectively reduce the average size of fish in a population, as well as total numbers. Brown trout did not show the same increase in numbers and average size concurrent with reduction in lamprey numbers, as furunculosis kills a high percentage of spawning brown trout, thus negating the beneficial effects of lamprey control.

Total mortality patterns differed greatly between brown and rainbow trout. Rainbow trout showed a relatively constant annual mortality (68%) for fish age VI and older. No drastic mortality occurred at any particular age. Brown trout, however, had a very high (89%) mortality at age IV, the most abundant age group in the spawning population. Few brown trout apparently survive their maiden spawning run, due mainly to the effects of furunculosis.

Annual fishing mortality estimates based on tag returns are relatively low for both rainbow trout and, especially, brown trout. Minimum exploitation rates were 1.9% and 6.0% respectively for brown and rainbow trout, not taking into account tag loss and non-reporting of tags by anglers. More liberal estimates which are probably overestimates of exploitation rates, were 8% and 25% respectively for brown and rainbow trout, assuming only 60% tag retention and 40% of the tags reported.

Overall, size and age distributions and mortality patterns show no indication of overharvest of either brown or rainbow trout at present. Fish are of quality size and are present in numbers as good or better than during previous studies. Brown trout could probably withstand a larger harvest, since a high percentage of them die during their maiden spawning run of furunculosis or other natural causes.

Reproduction did not appear to be a limiting factor to migratory trout populations in the Brule River. Large numbers of juvenile brown and rainbow trout captured during electrofishing surveys of the upper river and several tributaries indicated that good natural reproduction was occurring, and demonstrated the importance of these areas as trout spawning and nursery areas. Observations on ages of downstream migrating juvenile rainbow trout (smolts) also indicated that reproduction probably was not a limiting factor. The largest percentage of rainbow trout smolts were age I, while scales from adult rainbow trout indicated that the majority of these fish had spent two years in the stream. The river probably produces more rainbow trout than available food and/or cover will support, and many of these smaller (age I) fish are then being forced downstream at a size when chances of survival are poor in the lower river or Lake Superior. Limiting factors, therefore, may be food, cover, and resulting smolt survival.

Tag returns from Brule River trout caught in Lake Superior illustrate the importance of the Brule River as a producer of trout for the lake fishery. Although most brown trout returns were caught near the mouth of the Brule River, rainbow trout tags have been returned from over a large area of western Lake Superior. More tags have been returned from Minnesota and Michigan waters than from Wisconsin waters of Lake Superior.

Creel survey data showed that 38,800 anglers fished on the Brule River from July 1978 through June 1979, for a total of 150,446 angling hours. Pressure in terms of total anglers was 33% higher than in 1973. Pressure downstream from U.S. Hwy. 2 was substantially higher than upstream. Approximately two-thirds of all anglers on the Brule River were residents of Wisconsin.

Numbers of migratory adult brown trout and steelheads harvested annually have increased since 1973, while numbers of smaller brown and rainbow trout harvested have decreased. An estimated 816 of 1,698 brown trout harvested from July 1978 through June 1979 were 13 inches or larger. Of 11,717 rainbow trout harvested during the same period, 7,742 were 13 inches or larger.

Harvest rates were highest for brown trout upstream from U.S. Hwy. 2, although total harvest of brown trout was higher downstream from U.S. Hwy. 2. Total harvest and harvest rates of rainbow trout were both highest downstream from U.S. Hwy. 2. Anglers on the upper river spent an average of 47.6 hours to catch a brown trout 13 inches or greater, while anglers on the lower river spent an average of 17.9 hours to catch a rainbow trout 13 inches or greater.

Brown trout measured during the creel survey ranged from 8.3 to 25.0 inches in length. Rainbow trout ranged from 6.0 to 29.9 inches and averaged near 18 inches overall. Rainbow trout 13 inches or larger (steelheads) caught by anglers averaged approximately 22.5 inches, which was larger than during the early 1960's or 1973 creel surveys.

Size and age structure of harvested steelheads roughly parallels that in the population, except that higher proportions of younger (age III and IV) rainbow trout were harvested. Sufficient numbers, however, of these younger steelheads appear to be surviving into the older age groups to provide larger trophy fish for the angler.

The Pacific salmons have not had any visible adverse effects on trout fisheries in the Brule River. Coho and chinook salmon have the potential to compete with fall spawning brown trout for spawning areas; while juvenile salmon could compete with young trout for available food and cover. Pink salmon may be less of a direct threat to trout than other salmons, because of life history differences. Coho and chinook salmon reproduction was documented in the Brule River system. Any adverse effects of salmon on trout populations may not occur unless numbers of adult salmon were to increase in future years.

Concerns as to possible adverse effects of increased river use on trout fishing may be justified, but claims that tubing and canoeing are physically damaging to trout habitat or have caused declines in trout populations in recent years seem unwarranted, as no supporting evidence has been documented. If anything, it is possible that trout, during periods of high river traffic, are kept in a more disturbed state and are less vulnerable to angling.

MANAGEMENT RECOMMENDATIONS

The Brule River fishery is a unique resource especially in its ability to maintain a reputation as a trophy fishery in the face of increasing angling pressure. This study showed that the migratory trout fishery was not biologically in need of more restrictive regulations, and that migratory brown trout could, in fact, withstand greater harvest. Given the general health of the fishery, we are allowed greater latitude in management directions and can consider regulations and management techniques that will improve angler satisfaction, so long as these techniques will not harm the fishery. Management and regulation of the Brule River fishery should, provided anglers favor such a concept, better reflect its trophy image.

Under a "management for quality" concept, regulations and management could be aimed at: (1) improving the status of migratory trout as trophies rather than food fish; (2) improving quality (size) of trout in the catch; (3) improving the genetic or adaptive qualities of trout stocks, i.e. manage for wild trout; and (4) improving the quality of the angling experience.

A lower daily creel limit would improve the status of these migratory trout as trophies, particularly for rainbow trout because of their greater angling vulnerability. In addition, more anglers would receive the psychological satisfaction of catching a limit of trout. Although the Brule River fishery has thrived in spite of increasing angling pressure, a lower daily limit might also act as a safeguard against possible impacts of continued increases in fishing pressure.

An increased length limit on brown and rainbow trout during the regular season might also be appropriate under a "management for quality" concept. Presently the Brule River has a 10-inch minimum length limit on trout during the extended season on the lower river. A similar length limit on brown and rainbow trout during the regular trout season on the entire river would protect nearly all juvenile migratory trout to smolt size and allow their escapement to Lake Superior, in addition to protecting small stream resident brown trout. Such a length limit would not affect sizes of adult migratory trout in the spawning run. For the stream trout angler not interested in lake-run brown trout or steelheads, a higher length limit might increase average size of available trout, increase the catch rate for trout (counting both legal and sublegal fish), and increase angler success (in catching at least one trout).

We believe there is presently no need to continue rainbow trout stocking, nor is there any need to resume brown trout stocking to increase the migratory brown trout population, in light of the apparently excellent natural reproduction of both species and evidence that populations present during the study were not attributable to stocking. Elimination of stocking and management for wild trout would seem more likely to benefit the genetic and adaptive qualities of the trout stocks, and would be consistent with the trophy image of the Brule River. Habitat that for many years was occupied by hatchery fish could be filled by additional numbers of wild trout that may result from protection under a higher length limit.

This study does not directly address the status of the stream resident brown trout population, or whether that population would benefit from stocking. If the decision was made to implement such a stocking program, the genetic integrity of wild trout stocks should be preserved, and possible impacts on other trout species, e.g., displacement of brook trout, should be considered.

Since January 1, 1982, the Brule River below U.S. Hwy. 2 has been open to year-round fishing, partly a result of a recommendation from this study. We believed that a year-round season on the lower river would improve the quality of the fishing experience by eliminating the "carnival-like" atmosphere of the traditional opening day, without significantly increasing trout harvest. Anglers will have additional fishing opportunities during years when river ice breaks up early, but during most years the lower river remains ice covered to within one or two weeks of the former traditional opening date, so a large overall increase in rainbow trout harvest is unlikely. Anglers may be able to better utilize some of the brown trout that still remain in the river before ice-out.

The following set of regulations is recommended as an alternative to the present set of regulations on the Brule River, as a means of management for a higher quality fishery:

Regular trout season (1st Saturday in May through September 30):

Length limit: Rainbow and brown trout - 10 inches; brook trout - 6 inches (same as at present)

Daily creel limit: 10 trout or salmon per day, of which only 5 may be rainbow or brown trout in aggregate (same as present regulation during May)

Extended trout season downstream from U.S. Hwy. 2 (October 1 to, but not including, 1st Saturday in May):

Length limit: all trout and salmon (except lake trout) - 10 inches (same as at present)

Daily creel limit: 5 trout or salmon per day of which only 2 may be rainbow trout.*

Additional management recommendations for the Brule River are as follows:

1. Trout habitat improvement aimed at increasing available food and hiding cover appears justified for increasing standing stock of trout, and to encourage a longer stream residency of juvenile rainbow and migratory

*This regulation went into effect on the Brule River as of 1 January 1984, based on the recommendation of this study.

brown trout which may result in better survival of smolts in the lower river and Lake Superior. Habitat improvement has been in progress on the Brule River and its tributaries since 1979, and should continue where feasible.

2. Existing trout habitat and water quality should be strictly protected throughout the entire Brule River watershed. Beaver dams should be eliminated wherever they occur on the Brule River and tributaries. Trout spawning and nursery areas as outlined in this report and by Niemuth (1967) should be protected from damaging physical alteration. Shoreline protection laws outlined in Chapter 30, Wisconsin Statutes, should be strongly enforced.

The following additional studies should be conducted in the future to address unanswered questions.

1. Habitat improvement projects should be evaluated to assess their impacts on the fishery.

2. Size structure of stream resident and migratory trout should be monitored for changes, in light of future increases in angling pressure and/or changes in angling regulations.

3. Specific factors which trigger downstream migration and determine size and age of juvenile trout at migration should be studied to determine how longer stream residencies might be encouraged.

4. The relationships between stream resident and migratory brown trout populations should be studied to determine the exact degree of distinctness between the two populations and how they may interact while spawning.

5. Studies should be made to determine if stream resident brown trout populations have declined and what factors may account for such a decline.

6. Studies should monitor future levels of reproduction of Pacific salmons and possible competition with trout for spawning areas, food, and cover.

APPENDIX A. Common and scientific names of fish species found in the Brule River and tributaries (from Moore and Braem 1965, and the present study).

Common Names	Scientific Names
Lampreys	
Silver lamprey	*Ichthyomyzon unicuspis*
Northern brook lamprey	*Ichthyomyzon fossor*
Sea lamprey	*Petromyzon marinus*
Gars	
Longnose gar	*Lepisosteus osseus*
Salmons, trouts, whitefishes	
Brown trout	*Salmo trutta*
Rainbow trout	*Salmo gairdneri*
Pink salmon	*Oncorhynchus gorbuscha*
Coho salmon	*Oncorhynchus kisutch*
Chinook salmon	*Oncorhynchus tshawytScha*
Brook trout	*Salvelinus fontinalis*
Lake trout	*Salvelinus namaycush*
Splake	*Salvelinus fontinalis* x *S. namaycush*
Tiger trout	*Salvelinus fontinalis* x *Salmo trutta*
Lake herring	*Coregonus artedii*
Round whitefish	*Prosopium cylindraceum*
Smelts	
American smelt	*Osmerus mordax*
Mudminnows	
Central mudminnow	*Umbra limi*
Pikes	
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
Minnows and carps	
Carp	*Cyprinus carpio*
Creek chub	*Semotilus atromaculatus*
Pearl dace	*Semotilus margarita*
Lake chub	*Couesius plumbea*
Hornyhead chub	*Nocomis biguttatus*
Blacknose dace	*Rhinichthys atratulus*
Longnose dace	*Rhinichthys cataractae*
Finescale dace	*Phoxinus neogaeus*
Northern redbelly dace	*Phoxinus eos*
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Common shiner	*Notropis cornutus*
Spottail shiner	*Notropis hudsonius*
Blacknose shiner	*Notropis heterolepis*
Brassy minnow	*Hybognathus hankinsoni*
Fathead minnow	*Pimephales promelas*
Bluntnose minnow	*Pimephales notatus*

APPENDIX A. Continued.

Common Names	Scientific Names
Suckers	
White sucker	Catostomus commersoni
Longnose sucker	Catostomus catostomus
Silver redhorse	Moxostoma anisurum
Shorthead redhorse	Moxostoma macrolepidotum
Catfishes	
Black bullhead	Ictalurus melas
Brown bullhead	Ictalurus nebulosus
Yellow bullhead	Ictalurus natalis
Stonecat	Noturus flavus
Trout - perches	
Trout-perch	Percopsis omiscomaycus
Codfishes	
Burbot	Lota lota
Sticklebacks	
Brook stickleback	Culaea inconstans
Ninespine stickleback	Pungitius pungitius
Sunfishes	
Smallmouth bass	Micropterus dolomieui
Largemouth bass	Micropterus salmoides
Pumpkinseed	Lepomis gibbosus
Bluegill	Lepomis macrochirus
Rock bass	Ambloplites rupestris
Black crappie	Pomoxis nigromaculatus
Perches	
Yellow perch	Perca flavescens
Walleye	Stizostedion vitreum vitreum
Logperch	Percina caprodes
Johnny darter	Etheostoma nigrum
Iowa darter	Etheostoma exile
Sculpins	
Mottled sculpin	Cottus bairdi
Slimy sculpin	Cottus cognatus

APPENDIX B. Average daily high and low air temperatures (F) and extremes by month taken at the DNR weather station at Brule during the study period.

Year	Month	Average High	Average Low	Extreme High	Extreme Low
1978	June	79	47	92	34
	July	78	53	88	38
	August	80	53	94	36
	September	74	48	91	29
	October	60	34	76	19
	November	40	18	73	-16
	December	23	- 1	36	-27
1979	January	13	-13	28	-39
	February	21	- 7	47	-40
	March	38	16	52	-12
	April	51	25	75	2
	May	50	35	85	21
	June	77	44	88	29
	July	83	51	94	40
	August	77	51	85	32
	September	72	46	85	29
	October	56	33	72	16
	November	40	26	62	- 4
	December	33	14	53	-15
1980	January	22	1	42	-28
	February	25	- 1	39	-24
	March	37	8	54	-24
	April	60	28	87	15
	May	77	37	92	24
	June	79	49	92	30

APPENDIX C. High and low water temperature (F) at Hwy. 2 weir by week from July 19 to December 6, 1978 and 1979.

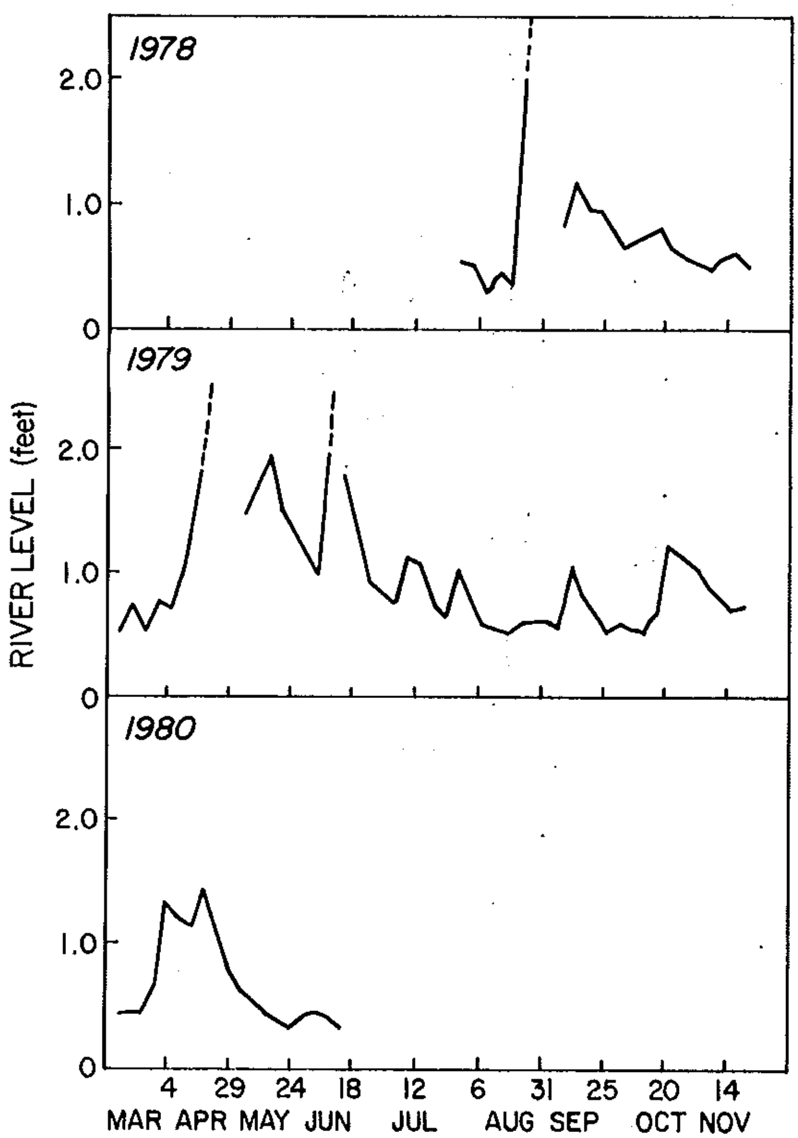
Dates	1978 High	1978 Low	1979 High	1979 Low
Jul 20-26	--	--	74	62
Jul 27-Aug 2	--	--	70	60
Aug 3-9	70	54	71	58
Aug 10-16	76	57	66	53
Aug 17-23	69	56	64	55
Aug 24-30	66	59	64	54
Aug 31-Sep 6	72	58	66	56
Sep 7-13	74	52	60	50
Sep 14-20	61	50	62	50
Sep 21-27	58	48	57	49
Sep 28-Oct 4	54	47	60	47
Oct 5-11	--	--	49	42
Oct 12-18	--	--	49	39
Oct 19-25	50	42	52	39
Oct 26-Nov 1	48	38	48	37
Nov 2-8	48	37	44	33
Nov 9-15	44	35	35	30
Nov 16-22	37	29	42	35
Nov 23-29	35	31	38	32
Nov 30-Dec 6	33	29	35	31

APPENDIX D. High and low water temperatures (F) at Hwy. 2 weir by week from March 8 to June 13, 1979 and 1980.

Dates	1979 High	1979 Low	1980 High	1980 Low
Mar 8-14	37	29	36	30
Mar 15-21	39	31	43	32
Mar 22-28	39	31	43	32
Mar 29-Apr 4	42	34	46	37
Apr 5-11	42	31	46	34
Apr 12-18	44	36	52	35
Apr 19-25	--	--	59	42
Apr 26-May 2	--	--	61	42
May 3-9	--	--	64	46
May 10-16	--	--	59	45
May 17-23	--	--	70	51
May 24-30	--	--	70	55
May 31-Jun 6	--	--	66	52
Jun 7-13	--	--	67	51

APPENDIX E. Monthly total precipitation (inches) during the study period at the DNR weather station at Brule.

	1978	1979	1980
January	--	1.12	1.88
February	--	1.79	0.45
March	--	3.90	0.98
April	--	1.23	0.81
May	--	4.54	0.78
June	2.23	6.06	2.63
July	6.90	6.88	--
August	7.84	2.31	--
September	3.32	2.91	--
October	1.94	3.63	--
November	1.90	1.54	--
December	1.36	0.44	--



APPENDIX F. River level fluctuations at Hwy. 2 weir during the study period. Broken lines indicate periods when river levels were above gauge.

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